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16. ABSTRACT
This report describes investigations conducted in the Columbia Basin, Washington, to determine the effects of irrigated farming and irrigation project operation on fish and wildlife resources. Field investigations focused on ring-necked pheasants, Canada goose, mallard, redhead, rainbow trout, and yellow perch, although other species are also discussed. Populations, nesting densities, habitat use, cover requirements, and effects of predation and human disturbance on pheasants during four seasons are discussed for six land use types. Seasonal populations, movements, and habitat use of waterfowl are related to three major wetland types. Data analysis also covered waterfowl nesting densities and brood production in relation to common carp, cattle grazing, human disturbance, and several wetland morphological characteristics. The study examines relationships between upland birds and waterfowl and agricultural crops, farming practices, operation and maintenance of irrigation canals and facilities, weather, and wildlife refuge areas. Lakes and streams are classified in Columbia Basin Project Area in relation to connection with irrigation water distribution systems. Physio-chemical features and invertebrate life of aquatic habitats are compared with fish populations, growth and condition factors. Recommendations are presented for maintaining or improving fish and wildlife in irrigated agricultural environments. Conclusions and recommendations, while developed for irrigation projects in central Washington, will be useful to water development agencies and wildlife managers everywhere.

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COLUMBIA BASIN WILDLIFE/IRRIGATION DEVELOPMENT STUDY

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December 1984

Applied Sciences Branch
Division of Research & Laboratory Services
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Denver, Colorado

Joint Report between the:
Bureau of Reclamation, Pacific Northwest Region, Columbia Basin Project Office, Ephrata, Washington;
U.S. Fish and Wildlife Service, Fort Collins, Colorado; and the
Washington Department of Game, Ephrata, Washington.

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

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The Columbia Basin Wildlife/Irrigation Development Study was an attempt to answer a broad array of questions concerning fish and wildlife relationships to irrigated farming. Its nature required the services of several agencies, each providing technical expertise and/or equipment, often without charge to the project. Principal funding was provided by three agencies: USBR (Bureau of Reclamation), FWS (U.S. Fish and Wildlife Service), and WDG (Washington Department of Game) under contract No. 14-06-100-8885. The WDG was responsible for conduct of field studies and preparation of reports. The principal investigators – Joseph H. Foster and Wallace E. Tillett – designed field studies, analyzed data, prepared the accompanying report, and accept full responsibility for its contents.

Wendell Oliver and Duane Eldred, both of WDG, developed the proposal for fish and wildlife studies. An advisory committee, comprised of USBR, FWS, WDG, and three Columbia Basin Irrigation Districts – Quincy, East, and South, was formed to review and assist in the conduct of studies.

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[1] U.S. Environmental Protection Agency.

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EXECUTIVE SUMMARY

Joseph H. Foster
Wallace E. Tillett

EXECUTIVE SUMMARY

WATERFOWL AND STATIC WETLANDS

Development of semiarid lands in the Columbia Basin for irrigated farming began on a large scale in 1952. As irrigation spread, ground-water storage increased, eventually surfacing to form many potholes, marshes, and perennial streams in depressions throughout the Basin. Waterfowl quickly capitalized on the new habitat and the Columbia Basin soon became the top waterfowl hunting area in Washington.

The attractive new habitat of the Columbia Basin Irrigation Project (Project) was not a planned part of irrigation development. Rather, it was a fortuitious byproduct and, as such, was not recognized as a legitimate purpose for development. Therefore, protection and perpetuation of habitat and waterfowl populations could not be legally demanded. Lack of protection became an increasing concern as waterfowl managers and hunters watched an alarming decline in ducks which began in the mid-1960's and continued through the next decade.

Objectives

Causes for the drop in waterfowl use of Project lands could not be substantiated beyond conjecture. Specific studies were needed to determine casual agents and to identify management alternatives to arrest and possibly reverse declines. In addition, recommendations were needed to guide development and management of other lands scheduled for irrigation development such that wildlife, as well as agriculture, would have perpetual benefits.

This report focused on salient features of Project operation, farming practices, and wildlife management practices affecting waterfowl populations in the Columbia Basin. Specific objectives were to determine:

(1) Physical and biological features of ponded water, including:

- a. Limnologic/hydrologic characteristics;
- b. Aquatic vegetation distribution;
- c. Rough fish abundance; and
- d. Nest predation;

(2) Features relating to water management:

- a. Relationship of wetlands to irrigation watercourses;
- b. Wetland drainage; and
- c. Reservoir drawdowns;

(3) Farming practices (including farming on public lands):

- a. Ground water pumping;
- b. Crop production; and
- c. Livestock grazing; and

(4) Institutional and social impacts:

- a. Human disturbance;
- b. Wetland ownership patterns; and
- c. Wildlife management conflicts.

Findings

Spring and Summer

The continued enjoyment of a large waterfowl population in the Columbia Basin has resulted from public ownership and management authority of a large portion of its many wetlands. Yet, ownership per se has no bearing on whether an area is used by waterfowl. Physical and biological conditions, as well as human use of a wetland, determine its value to waterfowl.

Waterfowl abundance (density) varied between wetlands under private, State, and Federal control. During early spring, there were 30 percent more ducks per acre on public-owned wetlands than on private waters. From late spring through summer, State-managed wetlands contained twice the density of ducks as did waters managed by Federal and private entities. Differences were related to the generally greater littoral area of State wetlands, extensive farming and vegetation control along shorelines of almost all private wetlands and intensive spring fisheries on many Federally managed waters.

Comparisons of all study wetlands showed many factors which influence waterfowl use during spring and summer. Wetland habitat in areas of low topographic relief are likely to provide the best conditions for spring and summer resident ducks because they offer a relatively high amount of shallow littoral area rich in aquatic plants and invertebrates. During spring and summer, these "saucer" type ponds harbor two to three times as many ducks per acre as do wetlands with steep shorelines. The "scabrock" lakes, with steep shoreline gradients, generally are of less value to spring and summer waterfowl because of a shortage of shallow areas.

However, scabrock coulees in the Basin often have relatively flat bottoms which may be diked or water levels regulated so as to provide excellent habitat for waterfowl production. A few waters occurring in rough, broken, scabrock areas appeared to be potentially good breeding habitat for ducks and geese, yet birds were seldom present. Factors believed responsible for waterfowl absence were human disturbance, high carp populations, and lack of nesting and brood-rearing cover as a consequence of excessive livestock grazing and herbicide use.

Although no significant relationship between wetland size and waterfowl numbers was found in early spring, duck numbers became heavily biased toward small waters as the season progressed into summer. Breeding pairs sought out small wetlands on which to nest and rear young. Brood densities were highest on ponds less than 1 acre in size, but ponds up to 5 acres still yielded relatively high brood numbers.

In the Basin, wetland formation remains a dynamic process even though irrigation development began over 30 years ago. Many standing water wetlands have been drained for crop production, yet new ones continue to form in low areas. The total area of surface water is higher now than at any time in the Project's history. However, most of this water is contained in a few large reservoirs. Large reservoirs become important for wintering birds, but in terms of duck production, many small clustered wetlands far outstrip the brood production of large lakes and reservoirs.

Large water bodies may produce fewer duck broods, but they are the principal breeding area for Canada geese in the Columbia Basin. This difference results primarily from presence of islands which are favored for nesting sites. Most smaller waters lack islands and are unused by geese. However, successful goose nesting has been consistently observed on islands in ponds as small as 10 acres in size.

Too few temporary lakes were included in the study sample to reliably describe their use by waterfowl. Complete desiccation of ponds has little impact on total production in the Basin at present. Yet, declining water levels on the Winchester-Frenchman Hills wetlands indicate temporary wetlands may become a critical factor in duck production. Extensive pumping from wells for irrigation has heavily capitalized on high ground-water tables and is believed to be an important factor in declining surface water levels near Winchester and Frenchman Hills Wasteways.

Ponds greater than 3-foot-maximum depth were favored by broodrearing ducks during late spring. Duck numbers were high on shallower marshes in early spring, but regressed in favor of deeper waters as summer approached.

Marshes over 3 feet deep usually maintained sufficient open water to attract ducks throughout the summer. Highest summer use by duck broods was on wetlands which contained 25 to 75 percent open water. Many marshes and shallow ponds in the study area were essentially closed habitats. Approximately 34 percent of the wetlands occurring along Project wasteways (free-flowing drains) were overgrown with cattails and bulrushes (i.e., 10 percent or less open water).

From midsummer on into early fall, duck broods were almost exclusively found on ponds which supported abundant submergent vegetation. Lack of submergents was directly related to presence and abundance of carp. The removal of carp is one of the most important management efforts which can substantially increase waterfowl use and production on many Basin waters. Three to four times as many ducks used waters without carp than waters having carp.

Of paramount consideration for new irrigation developments should be the separation of water delivery and return flow systems from spring creeks and lentic waters that originate from seepage. Carp dispersion throughout the Project has been greatly aided by canals and drainage systems. Many wetlands are connected only during brief periods of high water, but nevertheless have become contaminated. Keeping spring creeks isolated from Project waterways should be a high priority of future design criteria.

Both breeding bird numbers and duck production have been depressed by cattle grazing of wetland areas. Data for 1976 through 1979 revealed highly significant differences in duck brood sightings between ungrazed and grazed areas. Both dabbler and diver broods were two to three times more numerous per acre on wetlands which were ungrazed.

Present management of livestock grazing in the Columbia Basin has generally been detrimental to ducks and of limited value to geese. Close-cropped vegetation associated with livestock grazing is favored by foraging geese. But as found in this study, grazing yields benefits to geese only in specific areas. During spring and summer, geese benefit from cattle grazing mainly where it occurs near established nesting areas. As for small lakes, livestock use provides virtually no benefits, except on the very few areas where geese nest.

Grazing can be a most useful tool in managing waterfowl habitat in specific situations. Most commonly, a reduction in emergent aquatic plants (i.e., providing more open water) may be all that is necessary. For the semi-arid Columbia Basin, indigenous upland vegetation seldom needs to be grazed since it rarely attains densities unfavorable to upland nesting ducks such as mallard, teal, and gadwall. The results of this study showed that upland grazing during any season of the year had negative impacts on waterfowl production.

A major problem facing managers is conflict in management programs. Livestock grazing involves one such conflict, but nowhere is conflict more evident and more serious than in the issue of public used of wetlands. Waterfowl clearly need protected areas in all seasons of the year. Yet, managers are faced with public pressures to provide more and easier access to ducks, not only during the hunting season, but also for nonconsumptive viewing in spring and summer. The situation is further complicated by establishment of intensive spring fisheries on many Basin lakes and ponds which generally occur at a time when ducks begin setting up breeding territories.

Waters permanently closed to public use generally supported high duck densities in all seasons. Those wetlands used for recreation throughout the year exhibited the lowest amount of waterfowl use. Waterfowl avoided waters during spring through mid-summer when greatest recreational use (mainly fishing) occurred in this same period (April-July). Most of the latter group were potentially productive of waterfowl and were heavily used by birds during nonrecreational seasons. Where public use was principally from mid-October through January (hunting season), spring and summer duck densities were relatively high.

Recently developed management plans portend further habitat losses. Plans including fish introductions on former waterfowl areas, new roads, parking areas, trails, boat launches, and expansion of use agreements with private landowners will almost certainly prove detrimental to waterfowl and other wildlife. More appropriately, plans should consider increasing the number of waterfowl reserves and reducing the ease of access on much of the public waterfowl wetlands.

Nesting success for geese runs 80 percent or more as a result of their choosing isolated nest sites and generally high attentiveness to the nest. By contrast, the success rate of ducks in producing a brood falls well below 50 percent as shown in this study. Most nest failures appear to be a result of disruption by predators – 38 percent of all nests found in this study.

The best deterrent to predation losses, and possibly "voluntary" desertion as well, is the provision of large, undisturbed tracts of tall, dense vegetation. Duck nesting in the strips of cover associated with canal banks and roadsides is not only scarce but yields virtually no production because of predators. Most of the duck nesting attempts seen were in the wet soil zone bordering wetlands, an area which supports primarily sedges and bulrushes. In the majority of wetlands examined, this zone varied from 0 to 50 feet in width.

Plans for improving or creating duck nesting cover need not be concerned with so-called vegetational preferences. Any ecologically adapted mixture of broadleaf forbs and grasses is acceptable if they meet specifications for height and canopy coverage. Agricultural crops contribute little to duck nesting in the Project because of generally late season growth habits, mechanical disturbance or remoteness from brood rearing habitat. Since the majority of duck nesting occurs near (within 100 feet) static wetlands, management steps should aim at providing the best possible conditions in these areas. Undeniably, ducks will nest further away if cover is unavailable around the wetlands, but duckling survival decreases with increasing distance from water.

Fall and Winter

The dependence of wintering ducks on Columbia Basin corn crops has been poorly understood. High winter duck populations in the northern part of the Columbia Basin Project have been attributed to the abundance of field corn. Corn has certainly been a factor, but declines or egress from the North Basin (the area north of State Highway No. 26) do not appear at all related to abundance of corn. Major shifts in wintering areas have sent unprecedented numbers of ducks to southern portions of the Project and to the Umatilla-John Day areas along the Columbia River. These shifts have occurred when corn production in the North Basin has been greater than at any time in Project history.

Ungrazed corn stubble seems most attractive to field feeding ducks from late October through January during mild weather conditions. At present, the amount of fall cutting and disking does not appear to have reduced corn stubble availability below wintering needs of ducks.

Aside from possible production declines on northern (Canada) breeding areas, weather patterns and harassment seem to be the prime factors influencing wintering ducks in the North Basin. Except for the winters of 1968-69 and 1978-79, no significant changes in either onset or length of freeze-up periods or in amount of snow cover occurred. Even so, birds have steadily drifted away from the northern part of the Project.

The situation can be at least partially reversed by two management changes. First, hunting restrictions should be relaxed on the Columbia River at Umatilla Refuge. This would tend to break up some of the huge concentrations of birds, forcing them to seek other sanctuaries. To lure them back northward, waterfowl managers must provide several refuges in the North Basin. Both measures should be done in tandem to obtain greatest benefit. However, of the two, North Basin sanctuaries are the most critical. This has already been demonstrated by the recently created North Potholes Reserve.

Most of the factors which influence spring and summer use of various wetlands appear to have little significance during fall and winter. Distribution and size of the waterfowl population in the Project seem to be governed more by the need for quiet resting areas than any other factor. Food does not at this time appear to be a significant limitation to Project area ducks.

Refuges or reserves must also have guaranteed water rights – sufficient water to attract and hold a desired number of waterfowl through the winter. Recent changes in water storage in Potholes Reservoir threatens to eliminate the North Potholes Reserve as a very effective wintering area for some 60,000 to 70,000 ducks and geese. Planned development of irrigation should include water for wintering waterfowl needs as a high priority.

Recommendations

Water rights must be assured by not allowing anyone to deny purchase of irrigation water or prevent the use of ground and surface waters which may exist or be developed on a wildlife land parcel.

Ground water withdrawals for irrigation is a crucial factor which could be detrimental to waterfowl wetlands. Ground water dynamics are poorly understood and, therefore, need to be studied in detail before allotments are given near areas used by waterfowl.

Neither static nor flowing waters should be connected to irrigation watercourses at any time of the year to prevent ingress by carp and influents of suspended silts and organic matter from croplands and cattle feedlots.

Water-level regulatory devices should be installed in static wetlands wherever possible to control growth of cattails, produce waterfowl food plants, prevent establishment of carp, and lessen risks of botulism.

New wetlands which develop as a consequence of irrigation (those originating from elevated ground water or seepage) should be retained in public ownership and managed for waterfowl and other wildlife.

Static wetlands under 10 acres in size will provide the greatest return in duck brood production.

It is strongly recommended that nesting islands be provided in all wetlands to reduce loss of duck nests to predators and to increase goose nesting.

Large, undisturbed areas near wetlands are needed for upland nesting ducks. Ten acres should be considered as minimum; twenty acres or more would be ideal. Nesting plots should be designed in wide rectangle or square configurations rather than long, narrow strips. Minimum widths should be 200 feet. Nesting areas must be protected by fences and irrigated and fertilized as necessary for maintenance.

Vegetation plantings for nest cover should provide 100 percent groundcover at heights not less than 15 inches. Plant species selection should be guided by ecological suitability, cover and height requisites, and acceptability by agricultural intrests.

All habitat development areas should be fenced. Grazing should be eliminated near (within 100 ft.) wetland areas during all seasons of the year. Fenced lanes may be provided where access to water is needed by livestock. Where goose nesting occurs, small goose pastures can be developed on shorelines through cattle grazing, but these grazed areas should never exceed more than one-half of the shoreline perimeter.

Weed control should be limited to spot applications when herbicides are used. Broadcast spraying should be used only where noxious plants dominate large areas.

Wetlands which contain less than 25 percent open water because of vegetation (mainly cattails) encroachment should be opened up. Heavy concentrated grazing, use of herbicides, explosives and, to a lesser extent, fire are alternatives for vegetation control. The most effective control of emergent plants can be attained through water-level manipulation. This requires installation of regulatory structures and is advised wherever feasible.

Carp should be removed from waterfowl breeding and brood rearing areas. Diking, rerouting of feeder channels, installations of various fish barriers and use of piscicides should be used wherever carp become established in streams and small wetlands.

More large reserve areas must be established in the Columbia Basin. A portion of all new wetlands must be maintained as waterfowl breeding and wintering areas, completely free of human uses such as fishing, boating, wildlife viewing and hunting.

Provide incentives to private landowners to develop duck nesting cover along wetlands.

WATERFOWL AND IRRIGATION WATERCOURSES

Open delivery and drainage courses with a total length of about 3,200 miles supply over 543,000 acres of cropland with irrigation water in the Columbia Basin Project. The system is composed of main canals, lateral canals, and drains of varying width and flow capacities. Canals and laterals carry water during the irrigation season (mid-March to mid-October). During this time, ground water increases to the extent that upper soil strata become saturated. Excess water is bled off by an extensive network of surface and buried drains. As a result, drains usually flow throughout the year. Many of these watercourses are used by waterfowl for resting during migrations and also contribute to summer duck production. Because drains tend to remain ice-free during winter, they support a limited amount of duck use when static wetlands are frozen.

Objectives

The broad objectives of this segment were to:

(1) Identify waterfowl species and extent of use by facility, by season;

(2) Determine the kind of use made of canals and drains by waterfowl (i.e., resting, nesting, brood rearing, or other); and

(3) Describe ecological and physical features which influence use by waterfowl.

Findings

Duck use on 229 miles of canals, laterals, and open drains in the Columbia Basin was studied during the years 1977 to 1979. Seventeen species of ducks were observed on the watercourses. Mallard, blue-winged teal, and cinnamon teal comprised 77 percent of the observations. Redhead ducks were the most common of the eight diving species identified.

Except for diving species, watercourse size did not appear to be related to duck use. Divers were more numerous on large canals than the smaller drains and laterals. Flow velocities were low over all watercourses and were believed inconsequential to duck use.

Concrete-lined channels were generally avoided by adult ducks; less than 1 percent of the total observations were on lined channels.

Mallard, blue-winged and cinnamon teals, and redhead were the principal breeding species using the channeled waterways. Duck use was estimated at 4.2 ducks per mile on drains, 2.0 per mile on laterals, and 1.2 per mile on canals. Duck numbers were highest during late July, but declined rapidly thereafter.

Open drains, with their year-round flows, offered the only channeled waters available to ducks during the early part of the migration season. An average of 1.2 ducks per mile were observed on drains during this period. During the latter part of migration, canals and laterals also contained water. The average number of ducks was estimated at 1.8 and 2.4 birds per mile, respectively. Drains, at this time, sustained about 4.9 ducks per mile. The later migration period had the highest density of birds per mile on irrigation watercourses of any season.

Duck use of irrigation channels dropped sharply following the reproductive season. Densities on drains and canals were 3.0 and 0.8 ducks per mile, respectively. Canals and laterals lack water from late fall through early spring.

Very little duck nesting occurred on channel banks, one nesting attempt per 10.6 miles of bank. Lack of nesting was believed a result of poor vegetative cover. Undesirable plant species, spring burning, herbicide treatments, and livestock grazing limited vegetation cover development on watercourse banks.

Nine species of duck broods were found on irrigation waterways. Some 417 different broods were counted over the 3 years of study, with mallard and teal comprising 79 percent of the broods. Fifteen percent were redhead ducks.

Physical features as related to brood use were investigated on unlined canals, unlined laterals, and two drains. Four hundred brood sightings, including resightings, were used in the habitat use analysis.

Brood observations were related to bank type; duck broods used only reaches with earth-lined banks that supported vegetation at the waterline. Shallow coves on one canal supported as much as 55 percent of the observed broods.

Areas where broods were consistently seen along channels should be preserved for wildlife use. Grazing by livestock must be stringently controlled on these wetlands to attract breeding ducks.

Borrow areas and spoil piles should be covered with 3 to 6 inches of topsoil wherever possible. Vegetation plantings should be comprised of species beneficial to wildlife, yet present no weed problems to farming interests.

Traffic and other forms of mechanical disturbance have been identified as factors limiting waterfowl use of irrigation watercourses during the reproductive season. Therefore, vehicle traffic should be restricted to maintenance crews during spring and summer. Maintenance roads should be limited to one side of watercourses.

Vegetation control programs and grazing practices should be evaluated for costs and benefits. Alternative programs may prove more economical and also beneficial to wildlife.

PHEASANTS AND IRRIGATION DEVELOPMENT

Ring-necked pheasant is the most important upland game bird in the Columbia Basin and is second in abundance only to the mallard duck. Irrigation development of the semiarid lands of the Basin provided the kinds of habitat conducive to large pheasant populations. Early records (preirrigation) indicate that harvests of 18,000 to 30,000 birds per year occurred in Adams, Grant, and Franklin counties, the area of the present Columbia Basin Irrigation Project. As irrigation spread throughout the region, the population exploded. The peak harvest was attained in 1966 at about 260,000 pheasants. Thereafter, pheasants began a sharp decline which continued into the mid-1970's and gave impetus to this study in hopes that the causes for the decline could be pinpointed and alleviated.

Objectives

In addition to discovering factors limiting pheasant production on the irrigated lands of central Washington, pending development of the East High and the mandate of the Fish and Wildlife Coordination Act spurred interest in providing design features in irrigation plans which would enhance and protect the wildlife resource. The ultimate purpose of this study then was to provide engineering and management recommendations which, if enacted, would sustain high pheasant benefits over the life of the project.

Specific objectives as identified in the study's statement of work were numerous and are summarized as follows:

(1) Determine wildlife management and biological factors affecting pheasant populations;

(2) Describe effects of land use and irrigation design and management on pheasant populations; and

(3) Provide management and design recommendations to enhance and protect pheasant populations in new irrigation developments.

Findings

Labor intensive methods of farming characterized many of the early-day Columbia Basin irrigated farms. Furrow flooding required a maze of delivery and drain systems and consumed the landowner's time in operation and maintenance. With his hands full of normal farming activities, little time was left to clean up the odd areas or mow the weeds along field margins. Overapplication of water seeped through the soil mantle only to resurface at some other spot. Most of the early pheasant abundance resulted from inherencies of labor-intensive farming. To a considerable extent, many of these practices continue today but advances in technology have freed the landowner to clean up his farm and bring previously unused lands into production.

On the most intensively farmed sections of the Basin, 97 percent of the land is in crop production. Little cover remains for wildlife to use after crops have been harvested. About 83 percent of less intensively used lands also support crops. These sites and neighboring wildlife management areas furnish the majority of pheasants which scatter out into all lands during summer. When winter comes and the protective crop cover is gone, clean farms become pheasant deserts.

Development of irrigation in lands east of the Columbia Basin Project has given little respite. Pheasants occur on irrigated lands at about twice the density of that on dryland farms, yet private water developments have not benefited wildlife any more than if the land had been left as rangeland. Crops are somewhat more diversified, but not much. Field sizes are still large; but more importantly, the tightly restricted water use of center-pivot irrigation systems virtually assures no wetlands forming at present levels of development.

Pheasant densities were compared on the basis of land use intensity and differences in land use. Six canals had natural wetlands within 0.5 mile of the channel, with half the concentration areas within 0.3 mile of adjacent wetlands.

Land use proximal to watercourses appeared to influence brood use.

Duck brood observations were highest where undisturbed land bordered at least one side of the waterway.

Mechanical disturbance and human activity had a negative impact on brood use of riparian habitat.

Based on low resighting frequencies and a strong association with adjacent wetlands, duck broods used irrigation channels primarily as travel lanes rather than for rearing. Resightings were higher on drains, suggesting that some broods may have been reared entirely on the drain.

Most laterals offered few of the habitat requirements of brood rearing. Water shortages and severe fluctuations accompanied by a relatively high amount of human disturbance were the principal factors responsible for low brood use of laterals. Laterals which service large areas usually undergo few significant changes in waterflows, and hence, are more attractive to brooding ducks.

Canals had water throughout the brood rearing period and flow levels were constant. Lack of aquatic vegetation and its associated invertebrate animals severely limited food supplies for duck broods on canals and on laterals as well. Presence of coves and nearby natural wetlands were believed the most important reasons canals sustained high brood use.

Drains were the most heavily used watercourse by duck broods. Most of the habitat requirements needed by young ducks were available, largely because of year-round water supplies. Drains also had the lowest amount of disturbance of the three water types.

At least 1,624 duck broods are estimated to use open drains and unlined canals and laterals of the Columbia Basin each summer. Few ducks nest on the banks of irrigation channels. Most nesting occurs in croplands and undisturbed uplands, often far removed from good brood-rearing wetlands. Under present design and management, irrigation watercourses serve waterfowl most importantly as travel lanes, providing transport for duck broods from nest sites to brooding areas.

Management practices which remove plant cover from unnecessarily large areas preclude use of channel rights-of-way by ducks for nesting and brood rearing. Other wildlife species sustain similar adverse effects including loss of winter cover.

Management Recommendations

Design Features

Foremost in the design of irrigation watercourses should be the consideration of open channels as opposed to buried or pipeline distribution systems.

Channels with concrete lining are of no value to waterfowl. Therefore, natural materials should be used wherever feasible. Where seepage losses to the systems are excessive, the use of compacted earth or buried membrane are viable options with parallel drains on large canals and laterals appearing to be the most desirable of the three alternatives to concrete lining. With parallel drains, a belt of undisturbed land is created between the main delivery channel and the drain which provides additional cover and habitat for ducks and other wildlife. And the drain offers additional open water for waterfowl use. From the irrigators' view, parallel drains recapture otherwise lost water or at least reduce recovery expenses.

Duck production and general use could be increased in all irrigation channels by leaving short stretches of meandering channels undisturbed, by the creation of coves, such as exist in the East Low Canal, or by constructing ponds connected to the channel. For the latter, ideal locations would be at crossings of small natural drainage channels. A minimum of one cove for each mile of channel is recommended.

Drains and seep streams which have potential for year-round flows should be protected for wildlife use. Minimum flow levels should also be established to protect habitat which develops in these channels.

Fish barriers should be installed in drains where necessary to prevent ingress by undesirable fish, primarily carp whose bottom foraging causes highly turbid conditions and limits production of submergent aquatic plant life. Downstream drop structures not less than 2 feet high and permeable instream barriers in the upper reaches would eliminate carp contamination from other waters.

Buffer strips of uncultivated land should flank the channel banks. Where spoil berms occur, the strips should flank the outside base. Minimum strip widths of 50 feet are recommended. These strips, if left undisturbed, would create nesting sites and possibly year-round cover for many species of wildlife. Fences are recommended to protect vegetation cover on banks and buffer strips.

Channel Right-of-Way Management

Seep wetlands forming or existing near irrigation major land classes were recognized in the Columbia Basin:

(1) Intensively irrigated farming;

(2) Multipurpose lands;

(3) Wildlife production lands;

(4) Untilled lands;

(5) Dryland farming; and

(6) Private or incidental irrigation development.

The first three are in the existing Columbia Basin Project and under Federal water development contracts. The remaining three land classes occur in primarily dryland areas with a relatively low amount of unconsolidated water development. The latter classes lie to the east of the Project (East High) in what is proposed for full development by the Bureau of Reclamation.

Comparisons were made of pheasant densities by land-use class. Of the six alternative uses, dryland wheat farming is least conducive to meeting the needs of pheasants. The typical scenario of dryland wheat country is one of mile-upon-mile of uninterrupted tillage, a checkerboard of bare, fallow soil and wheat. Roadsides are farmed nearly to the asphalt. Only rarely do islands of natural shrubs punctuate the monoculture; it is these sparse oases which permit a few hardy birds to survive through winter.

Only four factors surfaced in this study which statistically correlated with spring and fall pheasant densities: (1) type of surface water; (2) topographic variation; (3) percent of adjoining sections with 15 or more acres of unused land; and (4) acres of unused land present on a section. Spring densities were highly correlated with these four variables (86 percent). Most of the influence was attributable to the amount of unused lands on the study section. The relationship was less strong for fall pheasant densities, much as expected. Spring correlations substantiate the dependency of wintering birds on the vegetation cover offered by unused lands. During summer and late fall, crops provide abundant cover and food; the birds need not rely on the idle tracts.

Cold weather and the snows of winter force pheasants to crowd into infrequent pockets of thermal cover, principally dense shrubs, willow patches, and cattail stands. Wherever these stands occur near croplands, they are intensively used. Unfortunately, thermal cover has almost been abolished by clean farming practices. And even on less thoroughly cultivated farms, the trend points to fewer and fewer tracts of permanent cover.

Ditch banks and roadsides were found to provide the least amount of protection to wintering birds. Rights-of-way comprise over 70 percent of the unfarmed areas on intensively farmed sections. Therefore, it is these strips on which judicious vegetation management offers the greatest potential for benefiting pheasants and other wildlife. Habitat developments elsewhere likely will be fleeting unless substantial economic incentives are guaranteed the landowner.

On less intensively farmed sections, a fair amount of untilled land remains. Large parcels almost invariably support cattle. Unless they include wetlands, natural vegetation cover may be quickly reduced to levels unsuitable for nesting birds. As winter cover, grazed areas have only marginal value.

Based on both summer and winter surveys, a minimum of 15 acres in each section should be set aside for winter cover. Ideally, the set-aside lands should be divided into at least two tracts. These areas would also furnish nesting cover. However, since nesting success is very low on narrow strips (less than 25 feet wide), it would be more effective to "square up" the tracts.

Nest studies indicate that idle lands are of value only when vegetation exceeds 15 inches in height and is sufficiently dense to conceal hens from ground and aerial predators. Production could be improved by protecting nesting areas from grazing, fire, and chemical treatment. The majority of pheasant nesting occurs in alfalfa and irrigated wheat because these crops provide excellent nest concealment and are abundant throughout the Project. Pheasants which choose alfalfa suffer as much as 60 percent losses of hens and nests during the first cutting which occurs mid-way through the peak of incubation. Providing an acceptable dense nesting cover on undisturbed areas could yield as much as a 25-percent increase to the fall population.

Management Recommendations

Field observations indicated that the principal factor affecting the pheasant population in the Columbia Basin is the amount of undisturbed summer and winter cover. Recommendations for enhancement planning therefore center on this need.

Rights-of-Way

Canals, Laterals, Drains

Service roads along canals, laterals, and drains should be restricted to one side of channel to reduce disturbance to birds and provide more area for vegetation development.

Outside slopes of spoil banks and borrow pits should be seeded with mixtures of tall grasses, forbs, and native shrubs.

Topsoil additions and regular fertilizer applications may be necessary for plant growth on some parts of rights-of-way where subsoils low in nutrients have been exposed during construction.

Some areas should be provided irrigation water at least during the early period of plant establishment.

All habitat development plots must be protected from livestock, herbicide treatments, and fire. Burning of weeds should be restricted to inside slopes of watercourses, preferably within the area of maximum designed flow capacity. Herbicide applications should concentrate on target pest species and spot treatments, as opposed to present blanket coverage methods. Fencing is recommended to protect the outslope, borrow pit, and other right-of-way areas from livestock grazing.

The above recommendations imply that open canal and drain systems be employed in distribution systems of new irrigation developments. Furthermore, these rights-of-way must be acquired and held in public ownership to protect habitat development for wildlife.

Roadsides

Many of the same recommendations made for irrigation watercourses are also applicable to roadsides.

Additional benefits for pheasants could be gained from cessation of mowing until July 15. This delay would provide ample time for both pheasant and duck nesting to be completed.

Residual vegetation becomes a key element of nesting substrate for pheasant and ducks. Burning, tillage, or use of roadside rights-of-way for interfield roads should be prohibited.

Farmlands

Wherever possible, wet areas which develop as a consequence of irrigation should be purchased in fee title or long-term agreements made with the landowner to maintain these areas for pheasants and other wildlife.

A minimum of 15 acres per square mile should be set-aside for habitat development. Ideally, these set-aside lands should be divided into at least two tracts spaced 0.25 to 0.5 mile apart. Desirable shrubs, forbs, and grasses should be planted, fertilized, and irrigated as necessary for establishment and maintenance.

Travel lanes should be created at intervals no more than 0.5 mile apart. The most ideal spacing would probably be at 0.25 mile. Existing roadsides and watercourses could partly serve this function if good vegetation cover was maintained.

Such a distribution of habitat areas would not only increase numbers of pheasants, but provide a more even distribution throughout the irrigated area. Both nesting and thermal cover needs would be met by these areas. Dense cover on untilled areas would offer an acceptable alternative to nesting in alfalfa where high hen and chick mortalities presently occur.

Public Wildlife Lands

Eliminate grazing, especially where wildlife lands border cropland. On large expanses of wildlife lands, small grains should be planted where croplands are more than 0.5 mile distant. Several small tracts of up to 10 acres should be distributed over the area. Only minimal crop cultures are needed to provide winter food.

Water Rights

It is essential that all habitat development areas be granted rights to irrigation water for the life of the project. Without water, many areas will never develop sufficient cover vegetation or wildlife food crops to be of value.

WILDLIFE DAMAGE IN THE COLUMBIA BASIN

Overview

Within the Columbia Basin Project, wildlife and its associated recreational use are viewed with mixed emotions. Recreationists and recreation industries were elated over the increase in the wildlife abundance that was spawned by water development. But landowners, while deriving intrinsic pleasure from wildlife produced on their land, often viewed the wildlife explosion as an added cost to the production of farm commodities. Furthermore, the attendant rise in recreationists placed additional social and economic pressures on the landowners.

Objectives

As part of the Columbia Basin Wildlife/Irrigation Study, investigations were to address the problems imposed on landowners and farmers by the wildlife resource. The objectives of this aspect of the study were to:

(1) Identify the wildlife species involved;

(2) Identify the kinds of damage sustained by landowners;

(3) Assess the extent of damage; and

(4) Provide alternative recommendations for reducing or eliminating damages and losses to landowners.

Results

Review of wildlife agencies records for the 7 year period, 1974 to 1980, indicated an average of 53 complaints per year of wildlife-related damage. In view of the frequent and strong concerns voiced by public and private groups, it is interesting that so few complaints appear in the records. Certain sources have continually alluded to widespread, nearly incessant and devastating damages suffered by farmers as a result of wildlife in the Project area. Public agencies readily agree that wildlife damages are indeed a serious problem, yet the number of complaints suggests otherwise.

Coyotes were the single, biggest concern with 40 percent of the total complaints, mostly for losses of livestock. The majority of complaints came from livestock ranges in dryland areas. Within the irrigation Project, coyote problems are relatively few.

Beaver, pheasants, geese, ducks, and skunks, in that order, accounted for 48 percent of the complaints. Governmental agencies (Fish and Wildlife Service, Washington Department of Game, and Agricultural Extension Service) have worked closely to alleviate damage problems as they arise. However, record-keeping has been inadequate for many aspects of damage problems.

The serious incidence of damage involves mainly coyotes, waterfowl, and pheasants. Although crop losses or increased production costs from these animals are perennial, widespread and believed to be economically significant, virtually no attempts have been made to estimate either the extent of damage or dollar losses.

Summary and Recommendations

The majority of landowners rate problems with wildlife fairly low on their list of concerns. Rajala and Shew (1978) [1]* concluded after 2 years of study: "It is the unusual Columbia Basin landowner who considers wildlife to have negative impact." All agree, however, that they probably do experience some losses, but only infrequently do these losses become of sizeable consequence.

The most frequent complaint farmers had was in having to deal with recreationists – a consequence of having wildlife on their land. Based on our findings and that of others, economic costs to most landowners appear relatively small. Nevertheless, the costs of having wildlife on their land becomes a point of contention during planning for wildlife enhancement and in negotiations for irrigation expansion.

In light of present plans to expand irrigation in the Columbia Basin, the problem surrounding crop losses to wildlife should be investigated in considerable detail. Wildlife agencies cannot estimate the extent of damages with present data, nor can they do so at some future date unless large improvements are made in data collection methods. And, it is very unlikely that even a few landowners can accurately describe their own losses.

AQUATIC STUDIES

Static waters within the study area were grouped as either direct or indirect irrigation effect. A third group was composed of lakes void of fish. Within each group, specific physical, chemical, and biological features were tested for their importance to fish growth. Comparison of these features and fish growth between groups were used to identify the benefits of irrigation development to a fishery.

Physical Features

Lake morphometry and fish growth were not correlated. However, impoundments of uniform, shallow depths offer the least habitat diversity and minimum protection from fluctuations in water-level and temperature extremes.

While no values were determined for optimum morphometry, several lakes in the Columbia Basin Project can be viewed as models for development of future irrigation impoundments. Banks Lake and

* The numbers in brackets refer to entries in the bibliography at the end of each chapter or section.

Potholes Reservoir each provide a favorable combination of deep and and shallow water area. Depth to 120 feet occur in both reservoirs and the amount of littoral or shallow water area is extensive. The amount of littoral area needed for optimum fish production was not determined.

Impoundment size and accessibility are important to the maintenance of a sport fishery. Most seepage-formed lakes in the project are under 40 acres and are readily accessible by vehicle. The majority are managed as trout-only waters and, because of their accessibility, are fished to near depletion within the opening weekend of season.

Larger lakes and reservoirs provide a natural buffer to overfishing in the waters studied. Vehicle access to these larger sized waters was not considered excessive. Jameson Lake is 620 acres and has two vehicle access points.

Potholes Reservoir is 28,000 acres and has six vehicle access points open to the public. Lake morphometry had no measurable effect on water chemistry or invertebrate diversity and abundance.

Chemical Features

Fourteen of the eighteen water chemistry variables studied differed significantly between groups of waters. Chemical leaching from surrounding substrate combined with slow-flushing times create conditions toxic to fish. Lakes were void of fish with water chemistry exceeding the following: alkalinity (700 p/m); nitrate, NO_3 (4.0 p/m); phosphate, PO_4 (2.0 p/m); sodium, Na (400 p/m); total dissolved solids, TDS (1,400 p/m); and pH (9.1).

Water chemistry appears to be correlated to fish growth although the relationship was not determined. Significant differences in water chemistry were found between medium and poor producing perch lakes and between good and medium producing trout lakes. The importance of water chemistry in future irrigation development is whether or not fish can survive and carry out their life functions without debilitating stress. In areas where the soil is highly alkaline, the buildup of chemicals to toxic levels can be prevented by direct connection to irrigation flows.

Biological Features

Zooplankton are the most important food item of the game fish species studied. A total of 62 species of Cladocera and Copepoda were identified from 30 lakes. The number of species of zooplankton occurring in direct and indirect irrigation affected waters was not significantly different. However, lakes void of fish contained significantly fewer zooplankton species compared to the other groups. This difference is believed to be the result of highly alkaline water chemistry which only a few species can tolerate.

The abundance of benthic macroinvertebrates decreased significantly as irrigation influence increased. The foraging of carp and suckers, which gain access to lakes via irrigation canals, is considered to be the reason for this decrease.

A measure of the richness of the most dominant zooplankton and benthic invertebrates inhabiting a lake accounted for 90 percent of the weight gains of rainbow trout in seep lakes. The lack of accurate growth data for perch precludes a comparable analysis in lakes directly affected by irrigation.

Results of this study indicate that the most important factor to fish production in both direct and indirect irrigation-influenced waters is the dominance of specific invertebrate species. The dominance of the particular species is determined mainly by the nutrient or chemical makeup of the water and secondarily by factors such as interspecies competition and predation.

Transport of water into and out of impoundments is beneficial to mixed species fisheries. The seasonal migration of fish from one reservoir to the next via irrigation canals is a major factor in the maintenance of fish populations in some of the waters studied. Nutrient rich water is also carried into impoundments via canals which stimulate invertebrate production.

Flowing waters within the study area were grouped as either direct, indirect, or no irrigation effect. Specific physical, chemical, and biological features were tested for their importance to fish growth in the same manner as static waters.

Instream cover was found to be the most important feature contributing to fish abundance (numbers/acre-foot) in all flowing waters studied. Concrete-lined canals with no drop structures were lowest in cover value and fish abundance. Meandering earthen channels with plunge pools, pools and riffles, undercut banks, and instream vegetation offered the most cover and had the greatest abundance of fish.

Irrigation canals can be designed to efficiently convey water and provide cover for fish. Drop structures create a plunge pool that provides cover for trout and other game fish. Plunge pools allow fish to rest as current velocities are reduced at this point. They also provide a safe place in which to forage on incoming food items with reduced exposure to predators. Drop structures should be implemented frequently along the length of canals. In addition to providing cover, drop structures prevent upstream fish movement. This is critical to maintaining a trout fishery in canals where fish cannot enter the system above the drop structures.

Another design feature that provides cover for fish is a series of embayments on each side of a canal and located at equal intervals along its length. These embayments can be viewed as turnouts for fish passing through a canal. Designed properly, an embayment can provide depth for cover and vegetation for invertebrate production. These structures can provide a wintering area for fish caught between reservoirs during the time canals are without water. Embayments also provide a safe place for angling without interfering with routine canal operations and maintenance. Additional benefits derived from embayments are increased nesting sites for waterfowl and many nongame avian species.

Where irrigation canals enter or exit a reservoir, habitat is created that attracts feeding fish. Inflow structures that cause water to cascade over large rocks and boulders and create a plunge pool are preferable to low-elevation structures. Outflow structures that create white water conditions provide some of the best instream cover in areas that would otherwise contain few fish. Where possible, multiple inflow and outflow structures should be included in reservoir design to maximize this habitat feature. Earthen canals and ditches can be designed to enhance fish production. Banks should be stairstepped to reduce erosion and allow for the establishment of riparian vegetation. While some water loss will occur to maintain the vegetation, benefits will be realized in reduced maintenance of ditch banks, increased cover for wildlife, and increased food production for fish.

Rock gabions can be placed to create instream cover by funneling flows down the center of the channel while providing resting areas between the bank and gabion walls.

Dry coulees and ravines can be utilized to convey irrigation return flows, turning these areas into productive fish and wildlife habitat. Natural waterways such as these can be modified to increase their habitat potential. Deep pools can be created with a back hoe or other heavy construction equipment. Food-producing riffles can be formed with dump truck loads of rock and meanders can be made of the channel to reduce water velocities and create undercut banks.

The maintenance of a fishery is dependent upon a continual supply of water. In many of the earthen ditches, drains, and wasteways studied year-round, water was supplied by subsurface flows and wells pumping continually to lower the water table for farming. These situations have the greatest potential for maintaining a fishery. Since they do not dry up annually, aquatic plants become established and soon create a restriction to flows. Aquatic vegetation in earthen structures is one of the most important habitat features for fish production identified in this study.

The use of aquatic herbicides to control instream vegetation should be held to a minimum. Annual cleanouts should be reviewed to determine the trade-offs between clean canals and a sport fishery. Cleanout once every 2 or more years may be more cost effective.

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INTRODUCTION

INTRODUCTION

Scope of Study

This report describes results of work conducted under a contractual agreement between the Bureau of Reclamation (contract No. 14-06-100-8885), the U.S. Fish and Wildlife Service, and the Washington Department of Game.

The objectives of the study were first to examine the interrelationships between the operation and maintenance of a large irrigation project and fish and wildlife resources. Secondly, recommendations based on research findings were to be made such that the needs of fish and wildlife could be incorporated into the planning designs for new irrigation development in central Washington. Wildlife benefits, therefore, were to become a "project purpose" in development of public water for farm production. This study was intended to provide water developers with the means to sustain relatively high levels of wildlife benefits throughout the life of an irrigation project.

While this study was directed at the geographical setting of central Washington and its particular environment, the results and recommendations presented may be useful to individuals and management agencies wherever irrigated farming occurs in the Western United States.

Most of the data in this study were collected between 1975 and 1980, and analyses and report preparation done during 1981 and 1982. Principal effort occurred in the Columbia Basin Irrigation Project. Additional information was gathered from a few areas within the nearby Yakima Project.

Background on the Study Area

The Columbia Basin Project is a large water development which irrigates over 543,000 acres of fertile lands. Slightly over 2 million acre-feet of water are pumped annually from the Columbia River at Grand Coulee Dam to service the Project. From the Columbia River, water flows into Bank Lakes, then south through a 2,200-mile-long system of canals and laterals to lands up to 150 miles away. In the geographical center of the Project, irrigation return flows and seepage runoff are collected in Potholes Reservoir. This water is then recycled for irrigation of lands further south.

The Project was authorized by Congress in 1935, but it was not until 1952 that development of the semiarid lands began on a large scale (Bureau of Reclamation 1976) [1]. More than 2 million acres are contained within the Project. Of this, the Bureau of Reclmation was authorized to provide irrigation facilities to a little over 1 million acres. Approximately 50 percent has been fully developed. Plans for the development of the second half are underway, primarily to the east of the developed Project in an area known as the East High.

Precipitation in the Basin averages 6 to 9 inches annually, coming mainly during winter. Average minimum and maximum temperatures are 20 °F in January and 91 °F in July, respectively. The average annual temperature is 50.4 °F. Short periods with temperatures below 0 °F and above 100 °F are common.

Topography of the area consists of gently rolling land separated by deeply incised coulees of various sizes. These coulees were created by glacial melt waters during the Pleistocene epoch. These abrasive floods eroded enormous chasms into underlying basalt of the entire Columbia Plateau.

Soils of the area vary greatly in depth and productivity. The shallow residual soils are derived mainly from weathering of the Ringold Formation and basalt bedrock, mixed with volcanic ash and other eolian soils in glacial outwash. The higher lands of the Plateau, north and east of these desert and semidesert soils, comprise loessal loams of fine sand and silt. These are characteristically deep, water retentive, penetrable, and highly productive.

Because of variations in topography, soil conditions and early farming practices, some tracts of undeveloped drylands remain scattered throughout developed irrigated farming areas. Vegetation on these drylands typifies that of the Basin prior to irrigation: shrub steppe communities dominated by big sagebrush and bluebunch wheatgrass. Riparian plant communities existed around the 8,000 acres of wetlands at scattered locations throughout the preirrigation Project area.

As water distribution systems began to crisscross the area, ground-water storage increased, eventually surfacing to form many potholes, marshes, and perennial streams in depressions throughout the Basin. Today, water covers about 53,000 acres of the Project area.

The creation of numerous reservoirs, seep lakes, and streams set the stage for fishing opportunities unparalleled elsewhere in Washington State. Similarly, irrigated cropland and rising water tables vastly expanded the food and vegetative cover base and resulted in phenomenal wildlife increases. Game bird production reached peak levels between 1964 and 1966, then declined thereafter. By 1976, 10 years after the peak, the pheasant harvest had fallen to 143,000, a decrease of 117,000 birds. Waterfowl numbers declined also, but less severely than pheasants.

The attractive new habitat of the Project was not a planned part of irrigation development. Rather, it was a fortuitous byproduct and, as such, was not recognized as a legitimate purpose for development. Therefore, protection and perpetuation of habitat and fish and wildlife populations could not be legally assured. Lacking official sanctions, wildlife and its habitat were buffeted by changes in farm technologies and crop market economies.

Lack of protection became an increasing concern when wildlife managers noted the declines in wildlife during the late 1960's. Lands had been set aside for wildlife by agreements between wildlife agencies (Washington Department of Game, U.S. Fish and Wildlife Service) and the developing agency, the Bureau of Reclamation. However, these actions failed to stabilize wildlife numbers. The reasons for these declines and the factors which influence fish and wildlife production in the Columbia Basin Project became the focus of the investigations which are reported in the following pages.

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Chapter I

MANAGEMENT IMPLICATIONS FOR WATERFOWL IN IRRIGATED AGRICULTURAL DEVELOPMENTS: IRRIGATION CANALS AND DRAINS

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MANAGEMENT IMPLICATIONS FOR WATERFOWL IN IRRIGATED AGRICULTURAL DEVELOPMENTS: IRRIGATION CANALS AND DRAINS

A total of 3,529 miles of main canals, lateral canals, and open drains service the Columbia Basin Irrigation Project (Project) in central Washington (Bureau of Reclamation 1978) [1].[1] Many of these watercourses are used by waterfowl for resting during migrations and also contribute to duck production during the summer. The WDG estimates duck production at about one brood per mile on canals and drains of the Project.[2] Beyond this, little is known about waterfowl use of the irrigation waterways of the Project. Oakerman (1979) [2] reported on studies conducted in the Yakima River Valley, Washington, which included duck nesting and use of irrigation waterways. Searches of the literature failed to locate anything significant on this subject.

A major purpose of the study was to develop an understanding of the waterfowl use of these waterways, and of the physical features which promote or limit waterfowl use. Initially, the study focused on major engineering design features of drains and canals as they influenced seasonal use by waterfowl; e.g., channeled vs. unchanneled systems, canals with concrete lining vs. those unlined, and canal size and flow velocities. Early field work suggested modifications and refinements of these considerations could be made which would provide more useful information. To this end, the study objectives were defined to be:

1. Identify waterfowl species and estimate extent of use by season;

2. Determine the kind of use made of canals and drains by waterfowl;

3. Identify biological and design features which influence use by waterfowl, such as:

   a. Bank type (earth, concrete, or rock);

   b. Vegetation on canal/drain banks;

   c. Land use adjacent to watercourse;

   d. Proximity to other wetlands; and

   e. Traffic disturbance; and

4. Estimate duckling production.

Drains of the Columbia Basin Project exist in two forms: (1) excavated channels and (2) meandering, natural channels. Only channelized drains are dealt with in this chapter along with canals and laterals.

STUDY AREA

The study waters lie in the northern portion of the Columbia Basin Irrigation Project, principally within Grant County (fig. 1.1). Water feeding the Basin's irrigation system originates from the Columbia River at Grand Coulee Dam and flows south through scabrock lands to a division a few miles northeast of Soap Lake, Washington. At this point, two main irrigation arterials are formed: the 87-mile-long East Low Canal and its western counterpart, the West Canal, extending some 88 miles. The two canals skirt the northern, eastern, and western peripheries of the Project and feed a network of smaller branch canals (laterals). Laterals deliver irrigation water to farms too remote to be serviced directly by the main arterials. Excess waters are shunted from farmlands via buried tile and small surface drain systems to larger, strategically placed, open drains. Most drain flows are recaptured in Potholes and Scooteney Reservoirs in the central part of the Project and redirected through other canals servicing the southern end of the Project.

About 543,721 acres of cropland are thus serviced by 333 miles of main canals, 1,993 miles of laterals, and 1,203 miles of open drains. The West and East Low Canals average 40- to 50-foot bottom width and have an initial capacity of 4,500 to 5,100 cubic feet per second (Bureau of Reclamation 1976) [3]. Bottom width of lateral canals range from 2 to 36 feet. Their capacities vary with the amount of farmland to be serviced. Drains generally have a bottom width of 2 to 20 feet and also exhibit a wide range of flow capacities (Bureau of Reclamation 1976, 1978) [1, 3]. Both canals and laterals usually carry water only during the irrigation season which runs from mid-March through late October. During the irrigation season, ground water increases to the extent that upper soil strata become saturated. This excess water is bled off by a network of surface and buried drains. As a result, water flows in most drains throughout the year.

Channels are sealed with concrete lining on some reaches of canals and laterals to prevent water loss

[1] Numbers in brackets refer to entries in Bibliography at the end of the chapter.
[2] D. Galbreath, personal communication.

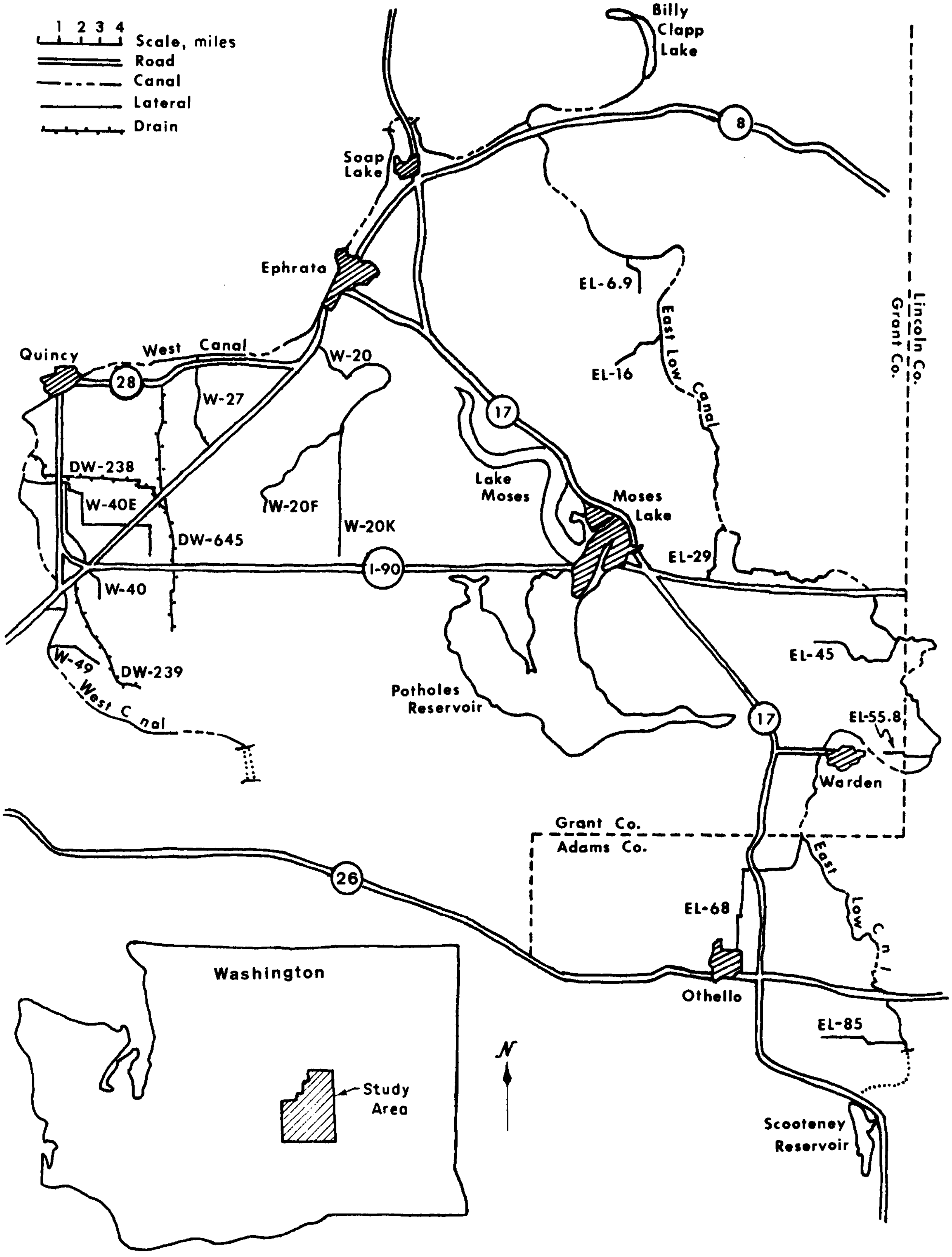

Figure 1.1.–Map of Columbia Basin, Washington, study area.

through highly porous substrates. Compacted earth forms the channel on remaining reaches. Where concrete lining is used, the lining extends a short distance above waterline. Project drains generally lack lining except on steep slopes or unstable soils.

To lessen erosion, channel banks are commonly seeded with crested wheatgrass, great basin wild rye, and redtop. Several other grasses, forbs, and a few shrubs have also become established through natural and accidental processes. Prevalent among the grasses are the ubiquitous cheatgrass and scattered stands of the native bunchgrasses, such as Sandberg bluegrass, bluebunch wheatgrass, and needle-and-thread. Common forbs include scouring rush, lambsquarters, kochia, Russian-thistle, knapweeds, and tumble mustard. Big sagebrush, rabbitbrush, and saltbrush comprise the principal shrubs occasionally found on channel banks.

Watercourse rights-of-way are sprayed with herbicides to reduce spreading of weeds by water, and to reduce waterway maintenance costs. Borne by stiff winds, Russian-thistle and tumble mustard become windjammed in channels and water flows are seriously impeded, requiring mechanical extraction during summer. Winter accumulations are burned by irrigators prior to irrigation season. Spring cleaning with fire often denudes the entire bank and proximal areas of residual vegetation, in addition to the channel bed.

Watercress and filamentous green algae represent some of the most common aquatic plants found in Project canals and drains. Drains, with their continuous flows, offer conditions best suited for aquatic plants, especially the rooted species. Control of aquatic vegetation is achieved with xylene, acrolein, or copper sulfate (Bureau of Reclamation 1976) [3].

Roads flank one or both sides of the waterways, providing access for routine channel maintenance. The roads also serve as driveways, access to crop fields, and connecting thoroughfares. Traffic is lightest along drains and heaviest along lateral canals.

METHODS

Preliminary observations began in 1976 on waterfowl use of the East Low and West Canals. Field work was intensified in 1977; and during 1978 and 1979, the study was expanded to include several lateral canals and drains.

Some 229 miles (6 percent) of the total 3,529 miles of open irrigation watercourses in the Columbia Basin Project were sampled for waterfowl use during the period 1977-1979. The total length of each sample watercourse type (canal, lateral, and drain) is given in table 1.1. Locations are shown in figure 1.1. In the interest of economy, all study waters were selected from the northern part of the Project. However, watercourses to the south did not differ in physical structure from those included in the samples, and the data are considered representative of the entire Project area. During 1977, only two canals were sampled. Waterfowl counts were made at approximately 2-week intervals from mid-April to mid-August. The following year, when other watercourse types were added to the survey, sampling intervals were reduced to about one per week, and the survey period was carried through mid-September.

The majority of information on waterfowl use was obtained through ground surveys. Aerial counts were made on two drains for winter use estimates, and for supplemental surveys in early spring on other watercourses. Canals and laterals were dry from mid-October to mid-March.

Observability of ducks was usually excellent (up to 0.5-mile distance) because of limited vegetation along watercourses. Duck broods occasionally made use of whatever meager bank cover was available for concealment. When brood concealment was suspected, the vehicle was stopped and the brood was flushed to identify the species and obtain a count of brood size. The following information was collected on canals during 1977: watercourse name, date of observation, waterfowl species, number and size of broods, estimated brood age class, channel type, and odometer reading at observation point. Surveys during late spring and summer of 1978 and 1979 emphasized both duck production and habitat use. Therefore, land use on both sides of irrigation channels was recorded at each brood observation point. Table 1.2 shows the classification scheme used for characterizing land use and the total length of land use for each watercourse. Land-use types were paired to reflect land-use differences or similarities from one side of a watercourse to the other at brood-sighting locations.

A broody hen was considered as evidence of a duckling brood being present and thus counted as one brood (Hammond 1970) [4]. Brood age class estimates (Gallop and Marshall 1954) [5] allowed back-dating to determine hatching dates for each brood. This, in turn, aided in obtaining reliable estimates of individual brood numbers. Resightings of an original brood during succeeding surveys were separated by comparing data on individual broods under the following assumptions:

Table 1.1.—*Length of channel type for each irrigation watercourse studied in the Columbia Basin, Washington*

Watercourse	Channel type,[a] in miles Lined	Unlined	Total, in miles
Canals			
West	13.7	33.9	47.6
East Low	23.5	53.1	76.6
Laterals			
W-20	0.1	11.7	11.8
W-20F	8.6	0.0	8.6
W-20K	3.5	0.0	3.5
W-27	0.0	8.2	8.2
W-40	0.0	7.6	7.6
W-40E	0.0	7.1	7.1
W-49	0.0	3.0	3.0
EL-6.9	0.0	2.8	2.8
EL-16	0.6	2.2	2.8
EL-29	0.4	3.2	3.6
EL-45	0.0	4.4	4.4
EL-55.8	0.1	2.0	2.1
EL-68	0.0	7.9	7.9
EL-85	0.0	4.6	4.6
Drains			
238	0.0	8.7	8.7
239	0.0	7.3	7.3
645	0.0	11.5	11.5
Totals	50.5	179.2	229.7

[a] Lined channels have concrete or rock lining the entire channel with the lining extending above waterline. No vegetation exists at the waterline on lined channels. Unlined channels are made of earth with vegetation on parts or all of the banks above waterline and dense vegetation growth at waterline.

1. The brood was unique to the watercourse,

2. Hatching dates were within 7 days of each other,

3. Observation points were within 5 miles of each other,

4. Physical barriers (syphons) in the channel prevented safe passage, and

5. The number of ducklings in a subsequent brood sighting was less than or equal to the number in the previous sights.

Detailed discussion of the methods have been presented in Hoag, 1980 [6].

Resightings were omitted in estimating brood populations. Brood density estimates (number per mile) were based on the total miles surveyed between 1977-1979.

Concrete-lined canals and laterals, all segments of canals north of Interstate Highway No. 90, and one drain were not sampled during 1979. Therefore, observations concerning brood habitat use were limited in the analysis to only those areas of canals, laterals, and drains sampled in both 1978 and 1979. Sample length of respective watercourse types used in analysis of brood habitat use is presented in table 1.3, third row. Resightings of individual broods were included in habitat-use analysis.

Areas which ducks appeared to use more consistently than elsewhere along the watercourse

Table 1.2.—*Land-use types bordering both sides of canals, laterals, and drains in the Columbia Basin, Washington (lined channels and areas not surveyed in 1979 have been omitted)*

Watercourse	Land use types, in miles					Total
	Und/Und	Cult/Cult	HAA/Und	Cult/Cult	HAA/Cult	
Canals						
West	1.7	4.6	0.2	4.9	1.3	12.7
East Low	2.3	9.8	0.4	27.3	1.6	41.4
Laterals						
W-20	8.8	1.0	0.6	1.2	0.1	11.7
W-27	3.5	2.7	0.4	1.4	0.2	8.2
W-40	0.6	2.4	0.3	2.3	2.0	7.6
W-40E	0.2	1.6	0.0	4.9	0.4	7.1
W-49	0.0	1.0	0.0	1.9	0.1	3.0
EL-6.9	0.4	0.7	0.1	1.6	0.0	2.8
EL-16	0.8	0.8	0.2	0.3	0.1	2.2
EL-29	1.0	0.6	0.1	1.5	0.0	3.2
EL-45	0.0	0.1	0.0	3.9	0.4	4.4
EL-55.8	0.6	0.0	0.0	1.4	0.0	2.0
EL-68	0.0	0.9	0.0	4.5	2.5	7.9
EL-85	0.1	0.2	0.0	4.2	0.1	4.6
Drains						
238	0.6	0.5	0.1	7.4	0.1	8.7
239	3.7	3.2	0.2	0.1	0.1	7.3
Total	24.3	30.1	2.6	68.8	9.0	134.8

Und—Undisturbed land producing no marketable vegetation crop, e.g., pasture, marsh, or spoil banks.
Cult—Cultivated land growing crops other than livestock.
HAA—Human activity area with daily human activity, e.g., municipal/industrial, residences, cattle yards.

Table 1.3.—*Number of watercourses, their combined length, and the total number of surveys*[a] *by year for three types of irrigation watercourses in the Columbia Basin, Washington*

Year	Canals			Laterals			Drains		
	No.	Length (miles)	No. of trips	No.	Length (miles)	No. of trips	No.	Length (miles)	No. of trips
1977	2	124.1	15	0	–	0	3	27.5	9
1978	2	124.1	43	14	77.9	52	3	27.5	42
1979[b]	2	54.2	12	9	64.5	31	2	16.0	8

[a] Includes aerial and ground counts. One trip was a survey of one individual watercourse.
[b] Canal reaches north of Interstate Highway No. 90 and laterals, or portions thereof, with concrete-lined channels were not sampled in 1979.

were examined to determine a possible relationship between presence or absence of nearby wetlands. Some wetlands were readily visible from access roads along the channel. Other wetlands were undetected in routine surveys because land forms blocked the view. All wetlands within 1 mile of the channel were delineated by false-color infrared aerial photographs. Other laterals were not examined because of infrequent waterfowl use. Areas of relatively high duck use were then checked for the presence of nearby wetlands.

Nest searches were also conducted along the main canals during 1976, 1977, and 1978 to determine the importance of canal banks compared with other land types in the Basin. The data also gave insight as to whether hens were nesting on the canal banks or elsewhere.

RESULTS

General Waterfowl Use

Seventeen species of ducks were identified during 212 survey trips on canals, laterals, and drains of the Columbia Basin Project between 1977 and 1979. Table 1.4 shows their relative abundance on study waters. Dabbling ducks made up at least 86 percent of 9,247 individual observations. Mallard comprised 51 percent of all observations. Blue-winged and cinnamon teal were the second most numerous duck group found on the watercourses (table 1.5). Redhead and lesser scaup were the principal diver species encountered. Gadwall, wigeon, pintail, and shoveler appeared in low numbers, but were fairly consistent users of the waterways during the 3 years of study.

Table 1.4—*Total observations of duck species by year on irrigation watercourses in the Columbia Basin, Washington (between year and between watercourse comparisons are inappropriate because the data have not been adjusted for variations in sampling frequency and sample size)*

	1977		1978			1979		
Species	Canals	Drains	Canals	Laterals	Drains	Canals	Laterals	Drains
Mallard	672	79	1,236	208	1,470	545	290	192
Gadwall	9	61	71	0	71	6	0	0
American wigeon	26	9	47	0	53	10	2	6
Pintail	19	9	27	0	159	14	0	0
Green-winged teal	4	20	40	1	44	2	0	0
Blue-winged teal	31	61	68	17	10	0	14	0
Cinnamon teal	112	97	147	28	62	18	4	4
Blue-winged/cinnamon teal	294	21	650	107	268	186	132	69
Northern shoveler	52	6	60	5	5	9	17	4
Redhead	46	0	494	35	34	95	20	19
Ring-necked duck	2	0	2	0	0	2	0	0
Canvasback	0	0	0	0	2	0	0	0
Lesser scaup	26	0	192	61	6	38	28	0
Common goldeneye	0	0	0	0	2	0	0	0
Barrow's goldeneye	0	0	4	0	0	0	0	0
Bufflehead	11	0	8	1	0	2	0	0
Ruddy duck	7	0	0	1	0	0	0	0
Hooded merganser	2	0	0	0	0	0	0	0
Unidentified duck	0	0	115	11	21	0	0	0
Total dabblers[a]	1,219	363	2,461	377	2,163	790	459	275
Total divers	94	0	700	98	44	137	48	19
Total ducks	1,313	363	3,161	475	2,207	927	507	294

[a] Includes unidentified ducks.

Table 1.5.–*Total number and percent composition of major duck species observed on irrigation watercourses in the Columbia Basin, Washington, 1977-1979*

Species	Total number	Percent of total
Mallard	4,692	50.7
Teal (all species)	2,511	27.2
Other dabblers	757	8.2
Redhead	743	8.0
Lesser scaup	351	3.8
Other divers	46	0.5
Unidentified ducks	147	1.6
Total	9,247	100.0

Spring Migration Period

Northward waterfowl migration through the Columbia Basin often begins in February. Mallard and pintail lead the way, followed a short while later by green-winged teal. By mid-March, most other ducks are starting to move. Migration tapers off rapidly near the end of April; nevertheless, late migrants and stragglers can be detected as late as June.

Irrigation drains which flow year round provide the only irrigation watercourses available to the earliest migrating species, yet migrants were present on drains in low numbers between late January and early March. Five of six surveys on two drains during this period yielded a total of only 68 ducks or an average of 1.2 birds per mile per trip (fig. 1.2). This figure should represent a nearly normal level of early duck use on channelized drains.

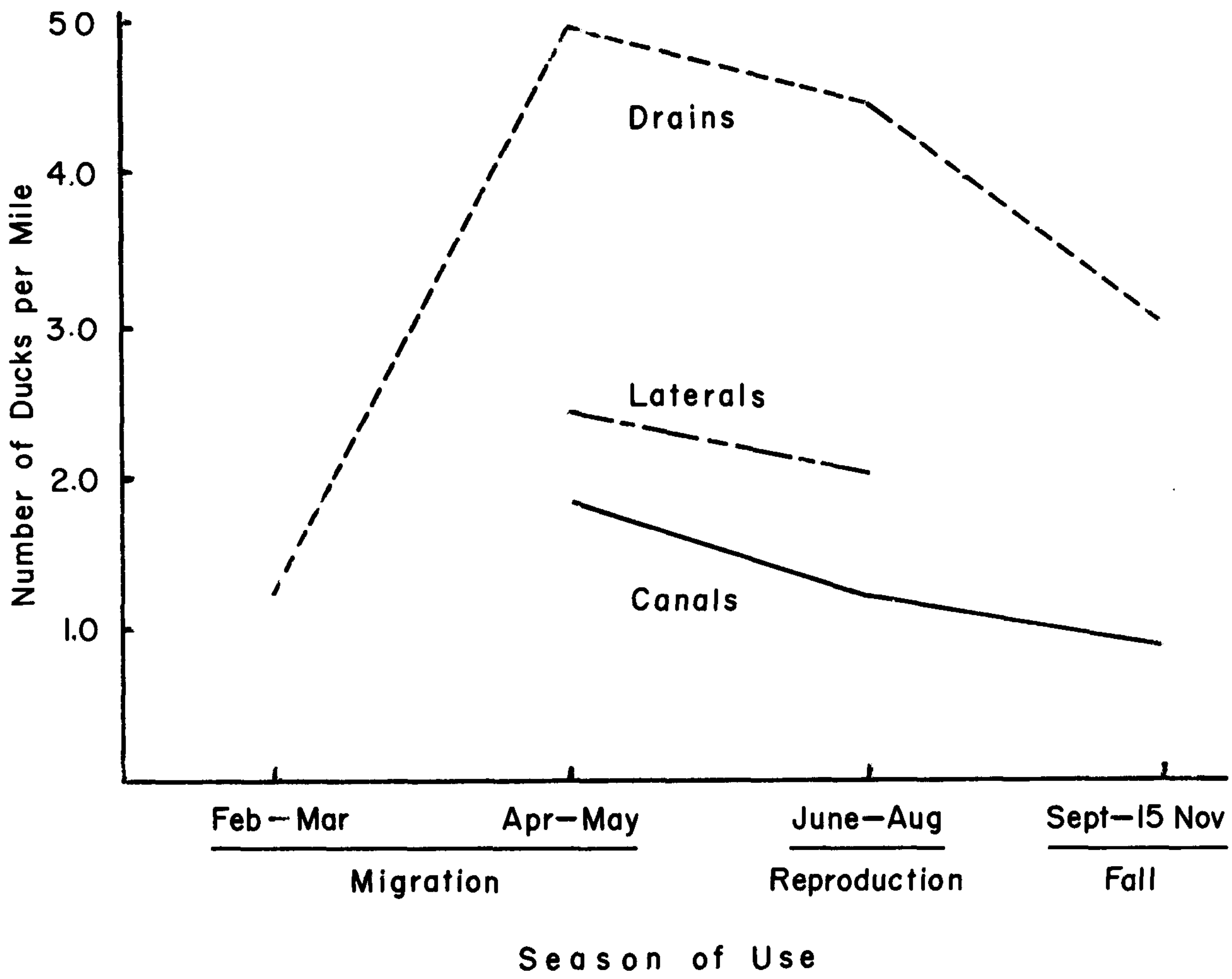

Figure 1.2.–Number of ducks per mile by season on irrigation watercourses of the Columbia Basin, Washington, 1977-1978.

Canals and laterals usually contain no water until about the third week in March and thus receive little early use by migrants. But since the migration pattern is such an extended phenomenon, late migrants have sufficient opportunity to use the canal system. With the filling of laterals and main canals near the end of March, considerably more Project watercourses become available for migrating ducks. A combined average was 2.2 ducks per mile for all watercourses during April and May (table 1.6). This period represents the latter end of migration for mallard, pintail, and green-winged teal. By late April, some of the mallards seen represent birds destined to spend their summer in the Columbia Basin. Thus, data in table 1.6 include breeders as well as migrants.

Table 1.6 and figure 1.2 reveal that near the end of migration period ducks used drains more than any other watercourse: 4.9 ducks per mile, as compared to 1.8 and 2.4 ducks per mile for large canals and laterals, respectively.

Ducks showed a decided "preference" for unlined canals and laterals during April and May. Only 3 percent of the total number of ducks observed were found on channels with concrete lining. None of the drains surveyed were lined with concrete.

Reproductive Season

The primary breeding ducks of the Columbia Basin are mallard, blue-winged and cinnamon teal, and redhead. These four species also make up the principal waterfowl users of irrigation watercourses during the reproductive season (table 1.7). Mallard and teal comprised from 74 to 84 percent of all ducks observed during the reproductive season. They made up a fairly constant percentage of the total ducks from one type of watercourse to another. Other dabblers, such as the gadwall, wigeon, and green-winged teal, constituted a larger percentage of the total on drains than on other watercourses. Numbers of divers generally declined with decreasing watercourse size (table 1.7).

Table 1.8 shows the number of ducks observed on watercourses during the reproductive season for all years combined. Numbers of ducks varied considerably between surveys, especially during June, but generally increased with each survey in July (figs. 1.3 and 1.4). Increases were most pronounced during the last 3 weeks of the month, reflecting duckling production. Figures 1.3 and 1.4 show a rapid decline in the use of the canals of the Project toward the end of August. The same pattern of use existed for laterals and drains.

Fall Season

Only eight surveys were made after 31 August. Counts were made on drains DW-645 and DW-239, once in October and again in November. West Canal and East Low Canal were surveyed for waterfowl once each in September and October, prior to dewatering in late October. With the limited number of surveys, the data are questionable as to their reliability. However, table 1.9 and figure 1.2 appear to show slightly lower use of large canals during the fall period than calculated for other seasons (cf. tables 1.6 and 1.8). This follows the trend indicated by figures 1.3 and 1.4 for the month of August. Drains, at 3.0 birds per mile, sustained a sharper drop in use from levels achieved during the two earlier seasons (cf. tables 1.6 and 1.8, fig. 1.2). Nevertheless, on a per mile basis, duck use of drains during autumn was over three times that for canals. No information was collected on duck use of laterals during fall.

Table 1.6.—*Total number of ducks and number per mile during April through May on irrigation watercourses in the Columbia Basin, Washington*

Watercourse	Survey miles[a]	Number of ducks	Number of ducks/mile
Canals	769.7	1,414	1.8
Laterals	94.6	229	2.4
Drains	88.6	435	4.9
Totals	952.9	2,078	2.2

[a] Survey miles = length of watercouses X number of survey trips made.

Table 1.7.—*Total number[a] and percent composition of major duck species by watercourse type during the reproductive season (June through August) on irrigation watercourses in the Columbia Basin, Washington, 1977-1979*

Species	Canals No.	Canals (percent)	Laterals[b] No.	Laterals[b] (percent)	Drains No.	Drains (percent)	Totals No.	Totals (percent)
Mallard	1,565	(41)	379	(48)	687	(49)	2,631	(44)
Blue-winged and cinnamon teal	1,250	(33)	258	(32)	485	(35)	1,993	(33)
Other dabblers[c]	286	(7)	39	(5)	172	(12)	497	(8)
Redhead	524	(14)	40	(5)	46	(3)	610	(10)
Other divers	192	(5)	79	(10)	6	(1)	277	(5)
Totals	3,817	(100)	795	(100)	1,396	(100)	6,008	(100)

[a] Includes ducklings.
[b] Data for 1978 and 1979 only.
[c] Includes unidentified ducks.

Table 1.8.—*Total number of ducks and number per mile during the reproductive season (June through August) on irrigation watercourses in the Columbia Basin, Washington, 1977-1979*

Watercourse	Survey miles[a]	Number of ducks	Number of ducks/mile
Canals	3,100.2	3,817	1.2
Laterals	393.3	795	2.0
Drains	333.5	1,396	4.2
Totals	3,827.0	6,008	1.6

[a] Survey miles = length of watercourses X number of survey trips made.

DUCK PRODUCTION

Nesting

Nest searches were conducted on about 120 miles of watercourse banks between 1976 and 1978. Only 11 nests were found.

Brood Populations

Broods of nine species of duck were observed on main canals of the Columbia Basin Project during the period 1977 through 1979 (table 1.10). Lower numbers of broods in 1979 reflect the omission of canal waters north of Interstate Highway No. 90. Approximately 83 percent of all original brood sightings were made on canal reaches south of Interstate Highway No. 90 in 1977 and 1978. Based on this, the total estimated number of duck broods using the West and East Low Canals in 1979 was about 100 broods.

Fewer species of duck broods were sighted on laterals and drains (six species, table 1.11) than on main canals (nine species, table 1.10). Mallard and teals

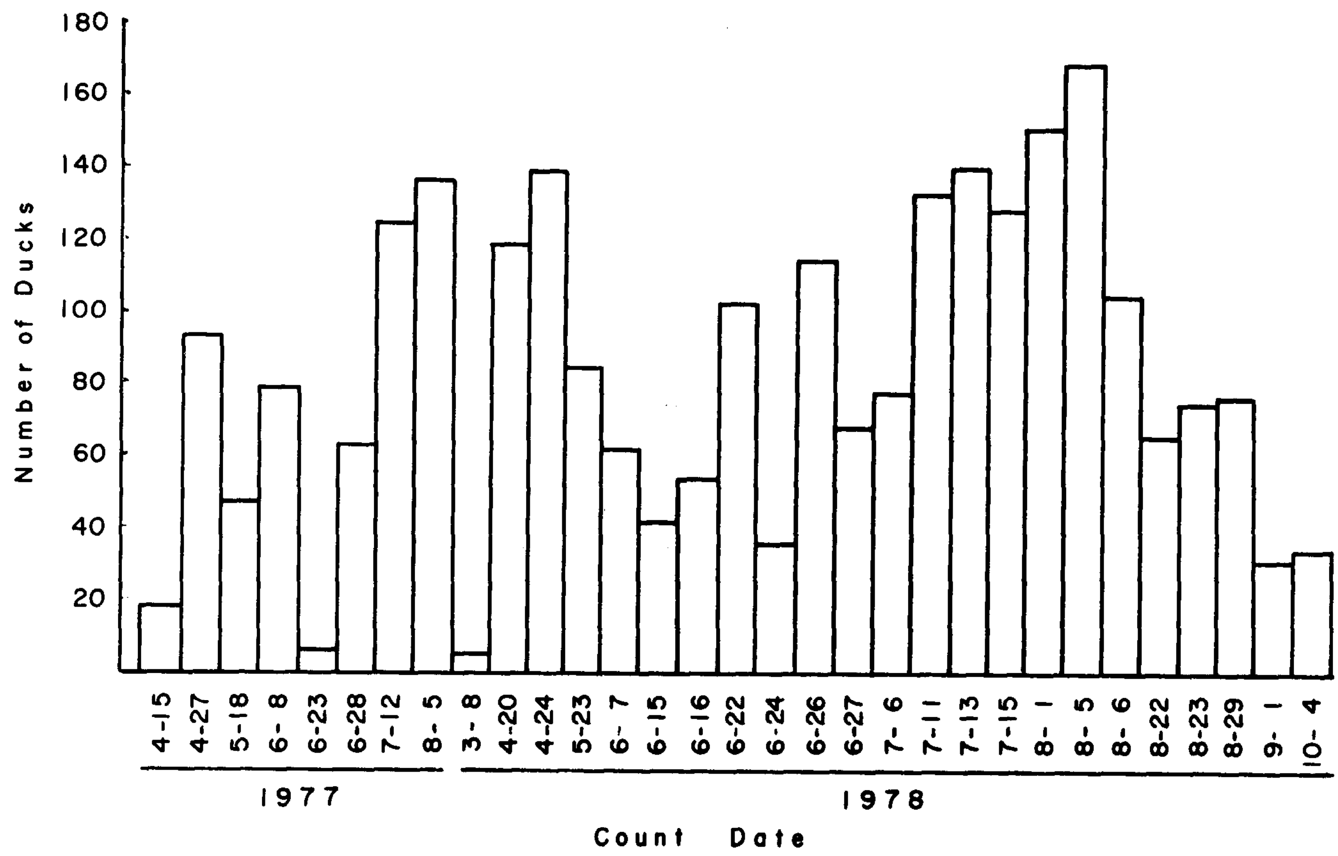

Figure 1.3.–Number of ducks observed by date on the West Canal, Columbia Basin, Washington, 1977-1978.

were the principal broods. Divers represented only 9 percent of the broods on laterals and drains compared to 17 percent on main canals.

Duck broods were most numerous on canals, laterals, and drains, in that order (tables 1.10 and 1.11). However, when adjusted to broods per mile of watercourse, drains ranked highest, followed by canals. Laterals had the lowest number of duck broods per mile (fig. 1.5).

For 1977 through 1979, an average of 1.0 brood per mile were seen on canals, excluding resightings. At 0.5 duck brood per mile, laterals exhibited the lowest lineal density of the three watercourse types. Drains had 1.6 broods per mile. Estimates for laterals and drains were based on 1978 and 1979 counts.

Hatching chronology ranged from mid-April to late August. The peak-hatching period occurred in mid-June (fig. 1.6). The average brood size was 5.0 ducklings over the 3 years of study.

Duck Habitat Use

General

In 1977, the focus of the study involved evaluating engineering features of main canals, such as presence or absence of concrete lining and flow velocities. Size and velocity were relatively equal in the sample canals.

Flow velocities in all structured watercourses were low over most of their reaches. High velocities and turbulence were characteristic of widely separated drop structures, short concrete chutes, and siphons. These structures made up less than 1 percent of watercourse lengths. They were avoided by waterfowl.

Of the three watercourse types, main canals were the only type where ducks were observed on concrete-lined channels. Even then, duck observations occurred only in spring and amounted to

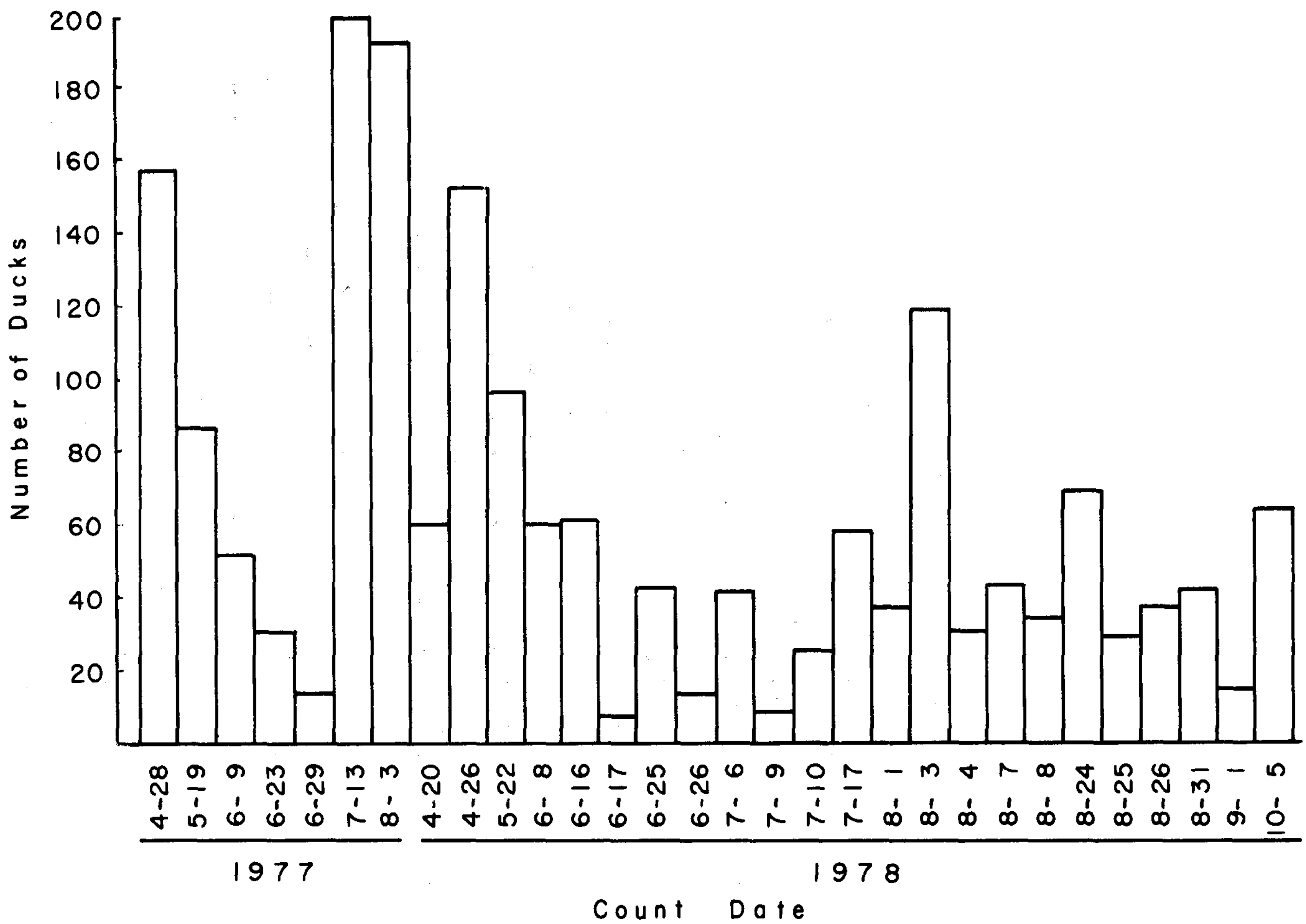

Figure 1.4.–Number of ducks observed by date on the East Low Canal, Columbia Basin, Washington, 1977-1978.

Table 1.9–*Total number of ducks and number per mile during September through 15 November on irrigation watercourses in the Columbia Basin, Washington, 1977-1979*

Watercourse[a]	Survey miles[b]	Number of ducks	Number of ducks/mile
Canals	178.3	144	0.8
Drains	37.6	112	3.0
Totals	215.9	256	1.2

[a] No surveys conducted on laterals during fall period.
[b] Survey miles = length of watercourses X number of survey trips made.

1 percent of total observations for the two waterways (table 1.12). Observations were highest on lined segments during April and decreased thereafter, with no sightings made after 1 June.

Characteristics of Brood Use

Results presented in this section address relationships between duck brood use and physical features of canals, laterals, and drains. Although referring to duckling broods, the results are equally valid for adult ducks.

In 1977, certain areas on both the East Low Canal and West Canal sustained relatively high and consistent duck brood use, an implication that duck use was related to certain channel features and nearby land use.

Table 1.10.—*Species and numder of duck broods observed on West and East Low Canals in the Columbia Basin, Washington (data for 1979 reflect observations south of Interstate Highway No. 90 only. Resightings of individual broods have been omitted)*

Species	1977		1978		1979	
	West Canal	East Low Canal	West Canal	East Low Canal	West Canal	East Low Canal
Mallard	22	32	13	21	25	18
Gadwall	0	0	1	0	0	0
American wigeon	2	0	0	0	0	0
Pintail	0	1	0	0	0	0
Blue-winged/cinnamon teal	14	17	24	9	20	5
Northern shoveler	1	2	2	0	2	0
Redhead	12	0	18	3	8	0
Lesser scaup	0	0	2	0	3	1
Hooded merganser	0	1	0	0	0	0
Canal totals	51	53	60	33	58	24
Year totals	104		93		82	

Table 1.11.—*Species and number of duck broods observed on laterals and drains in the Columbia Basin, Washington (resightings of individual broods have been omitted)*

Species	1978		1979	
	Laterals	Drains	Laterals	Drains[a]
Mallard	10	21	31	19
Green-winged teal	0	1	0	0
Blue-winged/cinnamon teal	6	14	10	5
Shoveler	2	2	1	1
Redhead	2	4	1	2
Lesser scaup	4	0	2	0
Totals	24	42	45	27
Year totals	66		72	

[a] One drain (DW-645) was omitted from the samples in 1979.

In analyzing habitat characteristics of brood use, all brood sightings, including resightings of individual broods, were considered. Of the 400 total brood sightings made in 1978 and 1979, 55 percent were seen on canals, 22.5 percent on laterals, and 22.5 percent on drains (table 1.13). Adjusting this to a standard unit of sightings per mile per year yielded 2.0 broods per mile on canals, 0.7 brood per mile on laterals, and 2.8 broods per mile on drains (fig. 1.7).

Physical features which affected duck brood use of structured waterways include bank type, presence or absence of bank vegetation, adjacent land use, proximity to other wetlands, and localized automobile traffic. With the exception of bank type, data relevant to physical features were gathered in 1978 and 1979.

Bank Type

Bank type was described as either lined or unlined channels. Lined channels are characterized by rock or concrete extending above waterline, whereas unlined channels have earth banks. Table 1.1 lists the lengths of each watercourse by bank type.

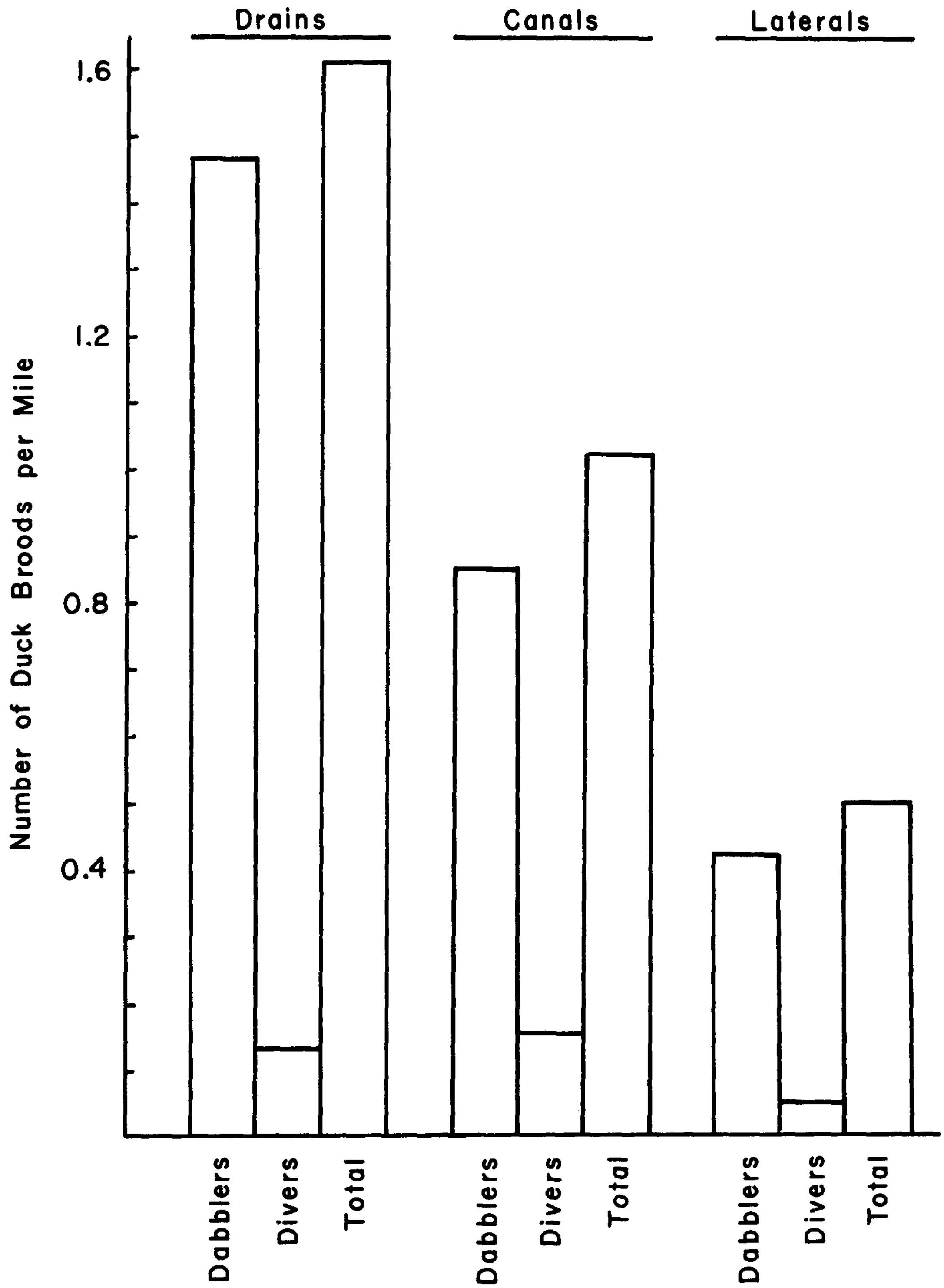

Figure 1.5.–Number of duck broods per mile on three types of irrigation watercourses in the Columbia Basin, Washington, 1977-1979. Brood counts were not made on drains and laterals in 1977. Resightings are omitted.

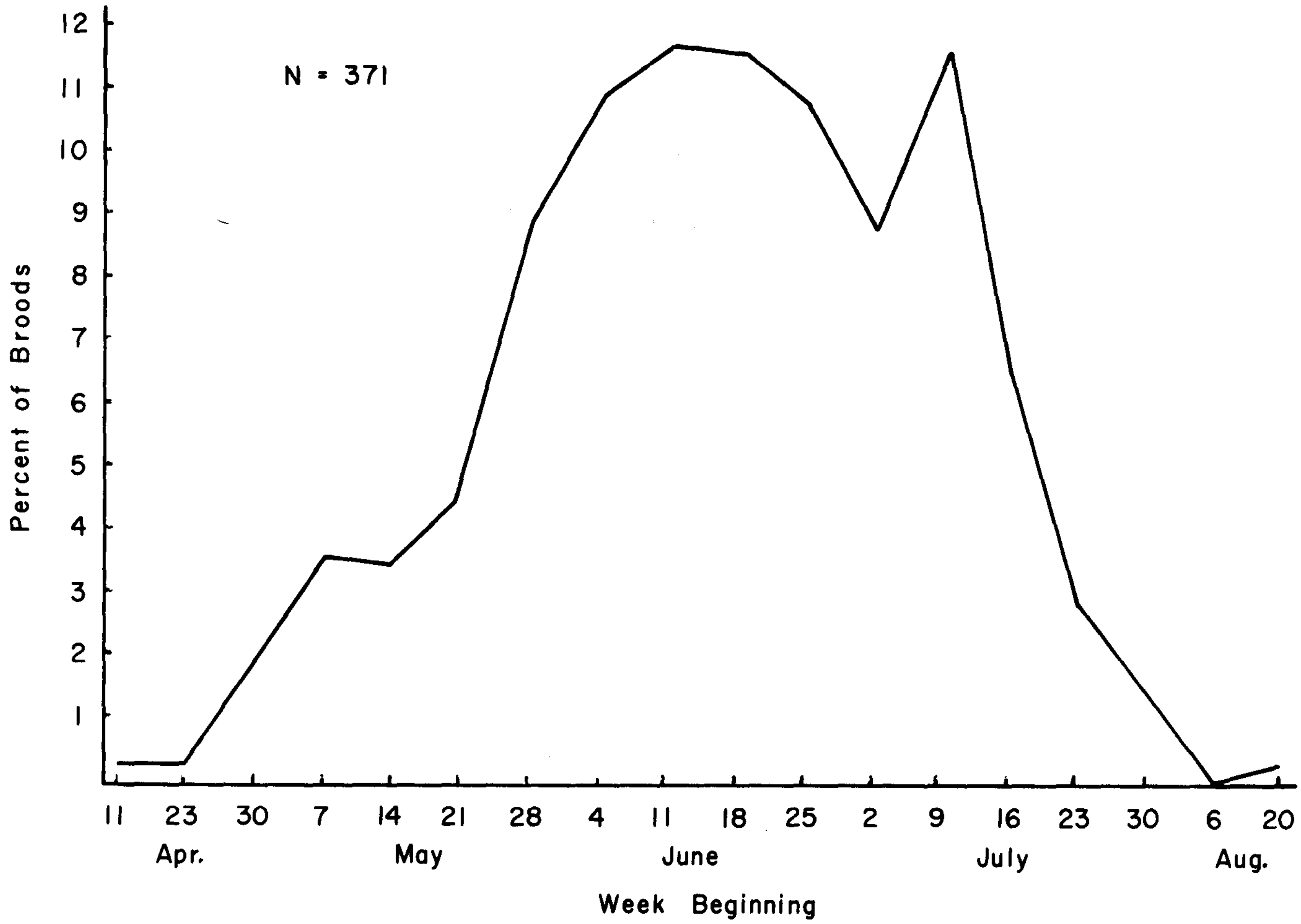

Figure 1.6.–Hatching chronology of duck broods on irrigation watercourses of the Columbia Basin Project, 1977-1979.

Duck broods were not observed on concrete- or rock-lined channels during either the scheduled surveys or during incidental travels throughout the 3 years of study. The only ducks seen on lined sections were adult birds in the spring (table 1.12). Portions of the East Low Canal south of Interstate Highway No. 90 had shallow depressions or coves along the east bank which were attractive to ducks and their broods. These coves occurred in areas where natural drainages intersected the canal and supported emergent plants such as cattails, bulrushes, and sedges. The coves were created during the construction of the East Low Canal and serve as silt-catching basins. Future plans mark their removal as the canal capacity is increased to accommodate irrigation expansion into the East High Area.

Water depth in the coves seldom exceeds 1 to 1.5 feet, and is generally less than 1 foot. In a few coves, silt has built up to form inlets a few inches above mean waterflow levels. Soils on these islands become sufficiently dry to permit establishment of grasses and forbs. Overall, cove vegetation shows variety and rankness both within and along cove perimeters. Presence of shallow, still water and heavy cover offer conditions rarely found on canals and laterals in the Basin. The shallow coves, found only on the East Low Canal, comprise only 21 percent of the canal south of Interstate Highway No. 90. However, 33 of the 60 broods (55 percent) were associated with the coves. Spring migrants also used the coves proportionately more than other reaches of the canal.

Bank Vegetation

Presence of bank vegetation, especially at or very near the waterline, appeared to partially determine whether a reach of watercourse was useable by duck broods. Lined canals and laterals, of course, had no bank vegetation at waterline. Unlined canals and laterals, for the most part, had at least a narrow strip of dense, tall grasses along the wetted perimeter. Drains nearly always contained lush growth at waterline, as well as higher up on the bank slopes. Also, both submergent and emergent aquatic plants frequently complemented the floral makeup of drain channels.

Table 1.12.—*Comparison of dabbling and diving duck counts by date on concrete-lined and earthen banks of two large irrigation canals in the Columbia Basin, Washington, 1977-1978*

Survey month	Species group	West Canal bank type		East Low Canal bank type	
		Concrete	Earth	Concrete	Earth
March	Dabbler	0	6	No count	No count
	Diver	0	0	No count	No count
April	Dabbler	25	402	22	408
	Diver	4	65	0	70
May	Dabbler	2	106	3	168
	Diver	0	21	0	11
June	Dabbler	1	556	1	252
	Diver	0	76	0	26
July	Dabbler	0	509	0	301
	Diver	0	97	0	33
August	Dabbler	0	498	0	535
	Diver	0	282	0	84
September	Dabbler	0	9	0	5
	Diver	0	22	0	10
October	Dabbler	0	25	0	65
	Diver	0	8	0	0
Totals		32	2,682	26	1,968
Percent		1	99	1	99

Table 1.13.—*Total duck brood sightings by species during habitat use studies on irrigation canals, laterals and drains in the Columbia Basin, Washington, 1978-1979 (resightings are included)*

Species	1978				1979				Combined			
	Canals	Lat.	Drains	Total	Canal	Lat.	Drains	Total	Canals	Lat.	Drains	Total
Mallard	31	13	29	73	53	45	29	127	84	58	58	200
Gadwall	2	0	1	3	0	0	0	0	2	0	1	3
A. wigeon	0	0	1	1	0	0	0	0	0	0	1	1
Green-winged teal	1	0	0	1	0	0	0	0	1	0	0	1
Blue-winged/ cinnamon teal	44	9	13	66	29	10	8	47	73	19	21	113
N. shoveler	4	2	2	8	3	1	1	5	7	3	3	13
Redhead	29	2	5	36	11	1	2	14	40	3	7	50
L. scaup	7	6	0	13	4	2	0	6	11	8	0	19
Total dabblers	82	24	46	152	85	56	38	179	167	80	84	331
Total divers	36	8	5	49	15	3	2	20	51	11	7	69
Totals	118	32	51	201	100	59	40	199	218	91	91	400

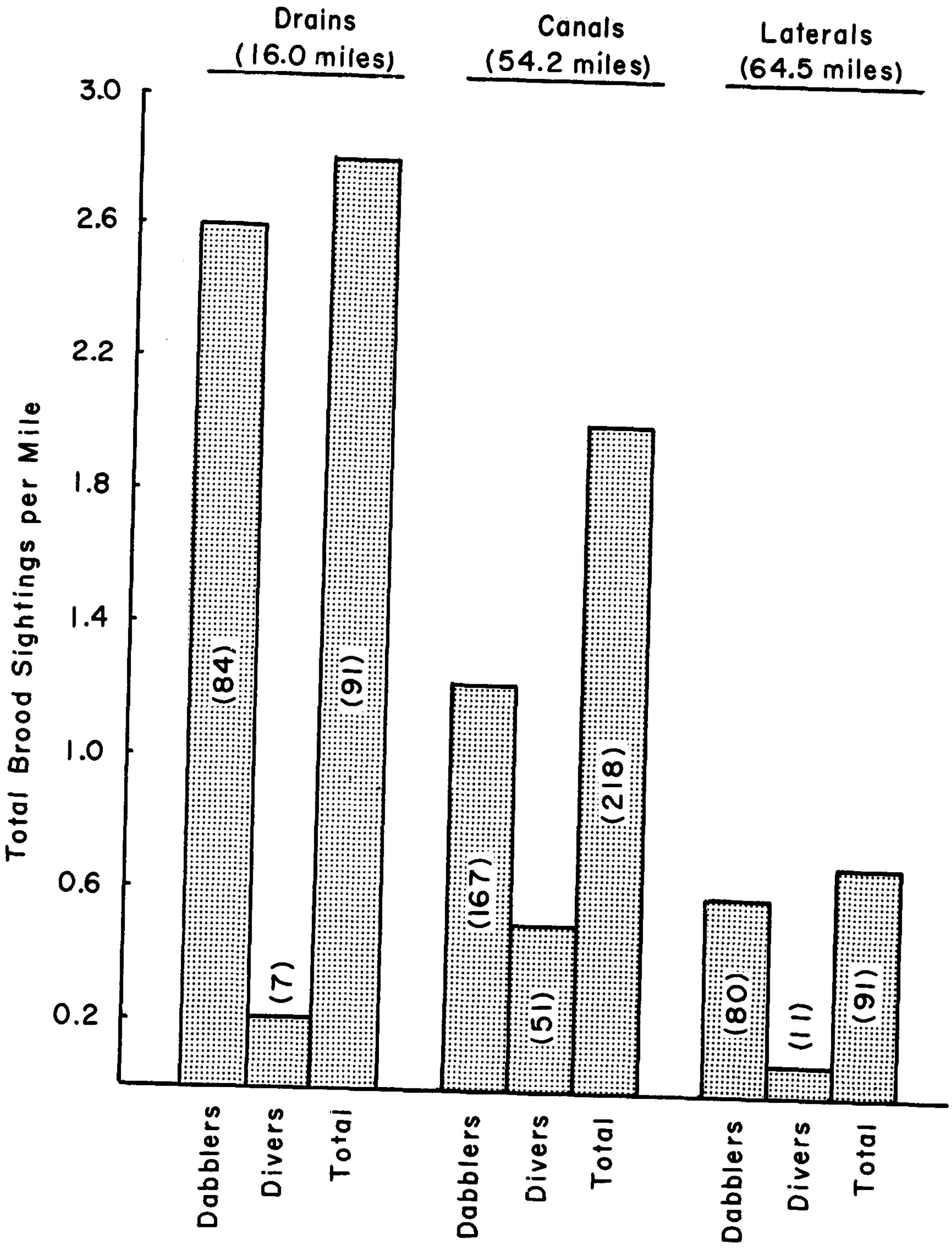

Figure 1.7.–Mean number of duck brood sightings per mile on canals, laterals, and drains in the Columbia Basin, Washington, 1978-1979. Resightings included. Numbers in parentheses are the total number of brood sightings made during the 2 years of study.

Several investigators have discussed the need of emergent or shoreline vegetation for brooding ducks (Gates 1965 [7] and Knight 1965 [8]). This vegetation serves as both protective cover and a source of food. Duck broods in this study usually took to the cover of overhanging grasses and cattail stands within a short time after detecting survey personnel.

No broods were observed on lined watercourses during the 3-year study, nor were they seen on unlined watercourses which lacked shoreline vegetation. Undoubtedly, some duck broods passed through areas lacking shoreline plants while in transit to other areas on the watercourse. However, observations of these watercourses and empirical evidence from elsewhere support the belief that areas lacking vegetation within the wetted perimeter are of no value to young ducks.

Adjacent Wetlands

Some reaches of the watercourses were used consistently by several duck broods. Reaches where five or more broods were seen regularly within 0.25 mile of each other, were termed "brood concentration areas." Brood concentration areas within waterway banks had physical features not unlike other areas along the channel. This led to the hypothesis that some environmental condition beyond the channels influenced use of a particular area by broods.

Using aerial photographs, adjacent lands within 1 mile of a watercourse were scanned for presence of wetlands. Comparing the location of brood concentration areas to adjacent wetlands revealed that all concentration areas were within 0.5 mile of a neighboring wetland. Furthermore, 50 percent of the brood concentration areas were within 0.3 mile of adjacent wetlands.

Land Use

Land use proximal to watercourse channels ranged from intensively farmed to residential/industrial to undeveloped rangelands. Since land use frequently differed from one side of a watercourse to the other, a system of "land-use pairs" was developed to describe conditions at each brood sighting point. Table 1.2 defines the land-use pairs and documents their length for each watercourse. Because neither ducklings nor adult ducks were observed on concrete-lined channels during the summer work of 1978 and 1979, no land-use pairs were identified for lined waterways.

Table 1.14 shows the number of brood sightings for each land-use pair. Duck broods showed a strong association with adjacent undisturbed land. Data in table 1.14 reveal that 74 percent of the brood sightings occurred next to a land-use pair that contained some undisturbed land. The data also tend to suggest broods were attracted to cultivated land; 61 percent of the brood sightings were associated with cultivated land on one or both sides of the watercourse. However, this apparent association is deceiving. By weighting brood frequencies on a basis of miles of a land-use pair available, the undisturbed/undisturbed pair had a 2-year average of 3.0 brood sightings per mile whereas the cultivated/cultivated pair had 0.7 brood sighting per mile (fig. 1.8). Overall, pairs containing undisturbed land averaged 2.6 sightings per mile (fig. 1.8). Pairs with cultivated land yielded 1.1 sightings per mile. Watercourse segments abutting undisturbed land consistently yielded the highest duck observation frequencies.

Access Road Traffic

Timed counts of vehicles on roads paralleling irrigation waterways were not made. Rather, determinations of traffic load were based on the relative frequency of vehicles observed during surveys. Automobile traffic was most frequent on laterals, less so on main canals, and least frequent on drains. Both the number of individual duck broods and total brood sightings per mile of watercourse was inversely related to the amount of access road traffic (figs. 1.5 and 1.7).

DISCUSSION

Nonreproductive Season

Literature on waterfowl use of irrigation channels appears scanty. The few references found dealt with the reproductive season, a fact not at all surprising since irrigation is needed only for the production of agricultural crops. Even so, most irrigation projects with canal delivery systems also contain some open drains which flow year round. These drains provide potential open water for ducks during winter. This appears not to have been considered by previous waterfowl researchers. Within irrigated farmlands of eastern Washington, very little is known about waterfowl use of manmade channels.

From late fall to early spring, Project drains provide the only channeled water available other than a few natural streams. Most drains flow perennially, drawing from supercharged ground waters which accumulate over the irrigation season. As such, channeled drains offer a wintertime alternative to frozen ponds and lakes while canals and laterals are dry. This alternative is, however, forfeited most of the time. In the dead of winter when lakes, marshes, and

Table 1.14.—*Total number of duck brood sightings relative to land use along irrigation watercourses in the Columbia Basin, Washington, during 1978 and 1979 (concrete-lined channels have been deleted)*

Watercourse	Brood sightings by land-use type[a]					Total
	Und/Und	Cult/Und	HAA/Und	Cult/Cult	HAA/Cult	
Canals						
West	54	65	4	29	5	157
East low	8	33	0	18	2	61
Subtotal	62	98	4	47	7	218
Laterals						
W-20	44	2	0	0	0	46
W-20F	–	–	–	–	–	–
W-20K	–	–	–	–	–	–
W-27	4	0	0	0	0	4
W-40	0	1	1	5	0	7
W-40E	0	2	1	11	0	14
W-49	0	4	0	5	0	9
EL-6.9	0	1	0	1	0	2
EL-16	0	0	0	0	0	0
EL-29	2	0	1	0	0	3
EL-45	0	0	0	2	0	2
EL-55.8	0	0	0	0	0	0
EL-68	0	0	0	2	1	3
EL-85	0	0	0	1	0	1
Subtotal	50	10	3	27	1	91
Drains						
238	23	9	1	15	1	49
239	14	21	1	6	0	42
Subtotal	37	30	2	21	1	91
Total	149	138	9	95	9	400

[a] Refer to table 1.2 for definitions of land-use types.

idle stream backwaters lie sealed with ice, ducks opt for bigger, ice-free water of the Columbia River to the west and south. The few thousand birds which remain on Project waters select free-flowing streams such as Rocky Ford and Crab Creeks, or the open, meandering channels of Winchester, Frenchman Hills, Lind Coulee and PE 16.4 Wasteways.

Discussions with waterfowl hunters who have hunted Project waters for many years indicate that duck use of channeled drains was quite high during the 1950's and 1960's. Information for October through February seems to indicate present use (1.2 ducks/mile) is but a fraction of that of past years as described by hunters. Reasons for the decline in winter use can only be speculated upon, but a number of facts are pertinent. First, wintering duck populations were higher during early years of the Columbia Basin Project (Foster and Tillett 1977) [9]. Second, the wetland complex of Winchester and Frenchman Hills Wasteways was incompletely formed during the 1950's and 1960's. In addition,

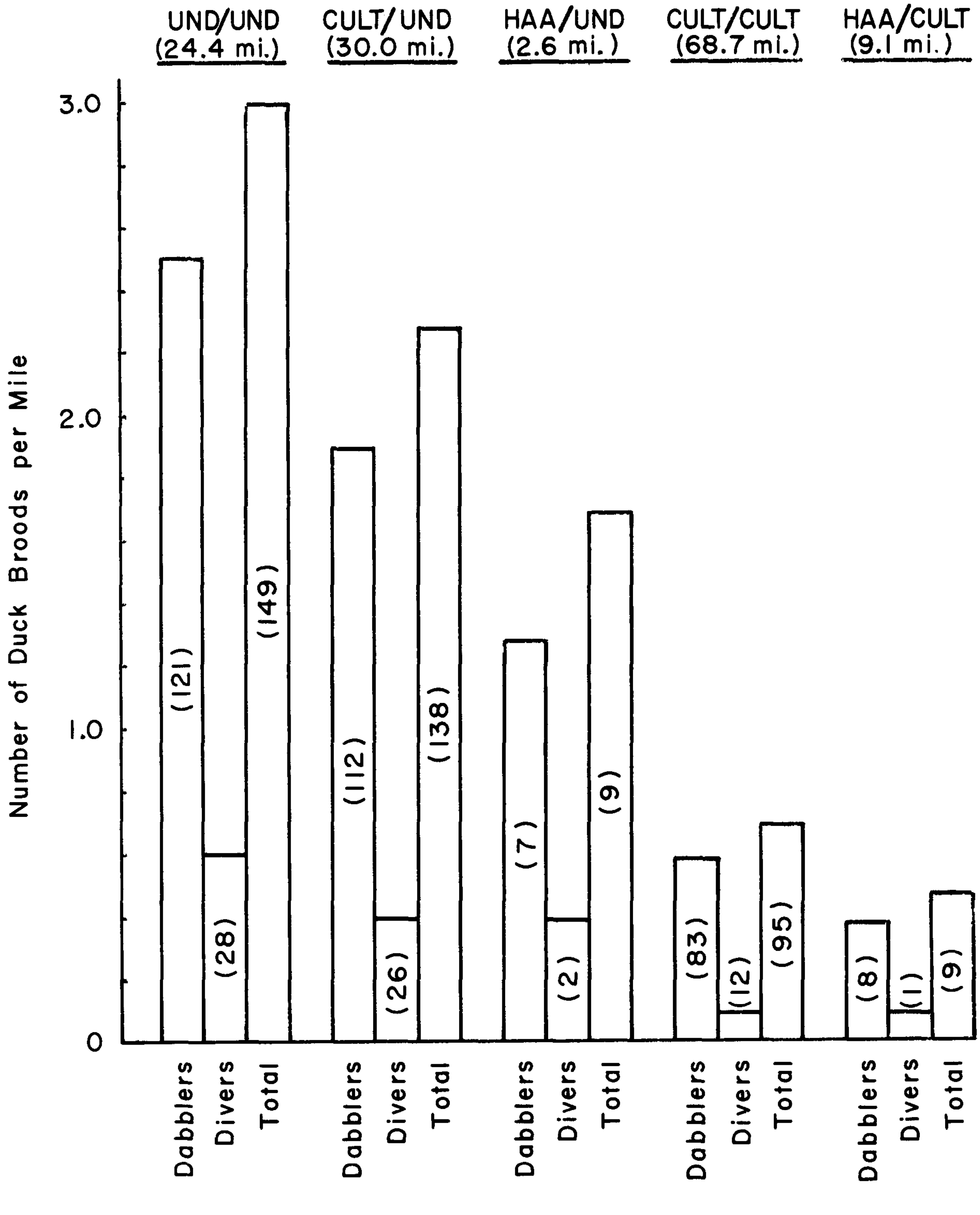

Figure 1.8.–Number of duck broods per mile of paired land-use classes along irrigation watercourses in the Columbia Basin, Washington, 1978-1979. All study waters are combined. Numbers in parentheses are the total number of brood sightings made during the 2 years of study.

large holding waters of Priest Rapids and Wanapum Pools on the Columbia River had not yet been created. Thus, during early Project years, fewer wetlands were available. Third, hunting pressure and other forms of disturbance have increased dramatically. Large duck populations interacting with fewer wetlands and lower disturbance could easily have accounted for the comparatively higher use of channeled drains in the past.

REPRODUCTIVE SEASON

Duck Densities

Observations on level ditches on the east coast (Wright 1954 [10], Carson 1964 [11]) showed little or no use by waterfowl during the reproductive season. Bonnema (1972) [12] reported that drain ditches installed to drain wetlands in Lac Qui Farle and Yellow Medicine Counties, Minnesota, failed to attract any of the several hundred breeding waterfowl formerly using the wetlands.

Contemporaneous work in the Yakima Valley conducted on 0.2-mile samples revealed generally low levels of use (1.6-2.8 ducks/mile) on main canals (Oakerman 1979) [2]. However, these linear densities were slightly higher than those observed in the Columbia Basin. The large canals in the Basin averaged about 1.2 ducks per mile during the summer reproductive season. For all watercourses combined, duck use was approximately 1.6 birds per mile (table 1.8). Reasons for the variation between the two areas may stem from differences in either habitat conditions, sampling procedures, or the presence of alternative habitat.

Nesting

Duck activity begins to pickup on all watercourses in March. Vernal migrants stop for a few hours or days, intermingling with fidgety pairs of local birds. For about a month, starting late in March, canals, laterals, and drains are used increasingly (figs. 1.3, 1.4). At the same time, wetlands near these watercourses fill to capacity, offering attractive brooding areas.

In time, migrants continue north. Those breeders left behind on channeled waterways become fewer as pairs move to other waters and hens seek nesting sites. By June, duck use dwindles to a few, presumably nonbreeding pairs, now and then a recently hatched brood, and an occasional lone drake.

Idle pairs and lone drakes were a familiar sight on some areas of canals and drains, especially near channel coves or adjacent natural wetlands. Some lone drakes appeared reluctant to leave when disturbed. This suggested that breeding territories included part of the watercourse.

Although Earl (1950) [13] found that mallards nested on spoil banks along irrigation ditches in California, only a few duck nests were found on channel rights-of-way and spoil banks in the Columbia Basin. Oakerman (1979) [2] concluded that much higher nesting occurred on canal and drain rights-of-way of irrigated farmlands of the Yakima Valley, Washington. They calculated nesting attempts at one per 5.4 acres or one per 1.1 miles of channel. But in North Dakota, Bureau of Reclamation investigators also found low nesting densities of ducks (one nest/23.8 acres) along the McClusky Canal of Missouri-Souris projects in 1977.[3] However, the following year densities rose to one nest per 4.0 acres. They concluded that increased nesting by ducks in 1978 resulted from above normal precipitation and increased residual cover in vegetational plantings.

Several studies have emphasized the importance of quality and quantity in vegetation cover as attractants to nesting ducks (Shearer 1960 [14], Cline 1965 [15], Duebbert 1969 [16], Dwyer 1970 [17]). A lack of suitable nesting cover along manmade watercourses in the Columbia Basin appeared the principal cause of disinterest by nesting ducks. The predominant vegetation on the rights-of-way consisted of grasses (bluebunch wheat grass, cheatgrass, redtop). Stands of caespitose species seldom occurred in appreciable densities, whereas cheatgrass, while dense enough, was limited by xeric conditions to growth of often less than 1 foot. Spring burning, herbicide spraying, and cattle grazing were prominent factors which also limited vegetation cover on canals, lateral, and drain bank.

Differences in nesting use in the Yakima Valley and the Columbia Basin undoubtedly reflect differences in abundance of vegetation cover along the watercourses. Typical irrigation rights-of-way in the former project offer taller and more dense cover during the reproductive season than are found in the Columbia Basin.

Brood Use and Habitat Relationships

In California studies, Earl (1950) [13] found that, in addition to nesting, irrigation ditches were used for loafing and for brood cover early in the breeding season. However, he reported that as soon as rice fields were flooded, duck broods moved off ditches into these fields. Based on low frequencies of nesting and

[3] T. Gatz and D. Krull, personal communication.

resightings of individual broods, duck broods in the Basin, as in California, used Project watercourses only for a short time posthatching. On main canals in 1977, only 25 percent of the total brood observations were resightings of an original brood. Resightings in 1978 and 1979, with more watercourses involved, were 30 percent. By dividing the average interval between brood counts (8 days) into the average fledging age for all species (48 days), each brood would, if it spent its entire life on the watercourse, have been observed six times before fledging. Between 1977 and 1979, the number of resightings was 1.5-1.8 per brood. If broods were spending all or most of their prefledging life on the channels, the resighting rate should have been much higher.

For these reasons, most duck broods used irrigation channels primarily as travel lanes or a very minor part of their home range. This hypothesis is supported by observations that a majority of broods were found on channel reaches with natural wetlands nearby. Sugden (1973) [18] reported that irrigation watercourses provided a means by which flightless duck broods could move long distances between wetlands. If this contention, which seems to have support in the present study, is valid, then perhaps the greatest value to waterfowl of irrigation watercourses under present design and management criteria is that of providing passage between nest sites and suitable brooding areas. Griffith (1974) [19] gave evidence that if suitable nesting cover cannot be found near brood-rearing wetlands, ducks may nest as far as 2 miles away. Duck nests have also been found in the Columbia Basin on sections far removed from good brooding areas. The problem then is getting ducklings safely to wetlands. In this regard, irrigation channels may play a highly significant role in brood transport and survival.

Based on the number of resightings on certain areas, a few broods were apparently reared entirely on watercourses; this conclusion is speculative in the absence of brood-marking experiments. Resightings, relative to canals and laterals, were proportionately higher on drains during both years of study. Drains characteristically offered better brood habitat. Better habitat and a greater resighting frequency suggest that broods were more likely to be reared on drains than on any other manmade watercourse.

Assuming that an average of 1.0 brood per mile used unlined canals, 0.5 brood per mile used unlined laterals, and 1.6 broods per mile used open drains, an estimate of total brood use may be projected for all similar watercourses of the Columbia Basin Irrigation Project. Based on 272 miles of unlined canals, 1,200 miles of unlined laterals, and 470 miles of unlined, open drains (excluding wasteways) (Bureau of Reclamation 1976) [3], some 1,624 duck broods use the Project watercourses each year.

This estimate should be considered a minimum in view of the sampling frequency. Between sampling runs, additional broods could have used the watercourses for a few days and gone undetected. Although efficiency of the surveys was undetermined, we believe that because cover was relatively sparse and channels offered few good hiding places, nearly all broods present during sampling runs were seen.

Successful rearing of duck broods requires habitat that has: (1) availability of water (Smith *et al.* 1964 [20], Munro 1967 [21], Dwyer 1970 [17]); (2) minimal water fluctuation (Earl 1950 [13], Salyer 1962 [22], Knight 1965 [7], Anderson and Glover 1967 [23]); (3) availability of cover (Beard 1964 [24], Gates 1965 [6], Dwyer 1970 [17]); (4) food in the form of aquatic vegetation and animal matter (Bue *et al.* 1964 [25], Knight 1965 [7], McKnight and Low 1967 [26], Sugden 1973 [18]); and (5) minimal mechanical disturbance and human activity (Beard 1964 [24], Hammond 1964 [27], Cassel and Oetting 1970 [28]).

In this study, concrete-lined irrigation watercourses provided water with minimal fluctuations, but lacked other habitat requirements. As a consequence, duck broods avoided lined watercourses entirely. Unlined canals provided most of the above-mentioned habitat requirements, although some requirements were in short supply. Water was available in canals throughout the brood-rearing period. Fluctuations in water levels were negligible. Cover on the unlined canal sections was usually present as dense grasses at waterline. Where high brood use areas occurred, cover was also available in shallow coves and in adjacent drains and natural wetlands. Because of the scarcity of aquatic vegetation and associated invertebrate animals, food supplies were believed a major limiting factor to brood use of canals. Canals had moderate amounts (relative to other water types) of mechanical disturbance and human activity.

Other salient features of habitat on main canals were land use practices on lands abutting canal rights-of-way and presence of natural wetlands. Earlier brood use was described in relation to adjoining land-use pairs. The presence of undisturbed land on one or both sides of a watercourse correlated with higher brood sightings along waterways. These factors combined probably had greater impact on brood use of canals than anything else. An area with this combination on the West Canal (about 3.5 miles long) comprised 27 percent of the canal surveyed below Interstate Highway No. 90. Yet this area contained

72 of 157 (46 percent) broods observed in 1978 and 1979. The canal in this area was bordered on the west by a small drain paralleling the canal bank for 93 percent of the reach. Irrigated pasture made up the remaining 7 percent. On the east side, the canal was flanked by pasture and undisturbed ground containing six small ponds (50 percent of the distance), a field of dense grasses and forbs, two ponds, and some marshy ground (25 percent). The remaining distance contained cultivated fields with a 60-foot belt of undisturbed vegetation between fields and canal bank.

Lined laterals, like lined canals, sustained no brood use. For unlined laterals, water availability was inconsistent and fluctuations of water levels were frequent and severe. Flows in laterals changed with the needs of farmers. These needs determined how much water, if any, was released into laterals.

As a general rule, severe water shortages and fluctuations of water levels were inversely related to lateral length. Long laterals serviced more farms and thus, were less susceptible to variations in flows. Because of frequent water fluctuations and drying of channels, laterals failed to provide adequate food supplies. Shoreline cover was frequently inferior to the needs of ducklings and had the highest levels of mechanical disturbance and human activity of the three water types in this study. In summation, most laterals provided almost none of the habitat requirements for brood rearing.

So it seems that with every rule, there is invariably an exception. The exception was lateral W-20. Lateral W-20 yielded 51 percent of all broods sighted on laterals, yet comprised only 15 percent (11.8 miles) of the total miles of laterals sampled. Lateral W-20 had habitat characteristics more typical of main canals than laterals. It had relatively constant flows, traversed more uncultivated area, typically supported both shoreline and bank vegetation, and had low levels of mechanical disturbance and human activity.

Drains seemed to best fulfill habitat requirements for duck broods. Waterflows were more dependable than with laterals and flowed year round. Permanent flows created an environment suitable for abundant aquatic plants and animals, therefore providing a rich source of food for ducklings. Shoreline and bank cover were generally more abundant than on canals and laterals. Drains also had the least amount of disturbance from machinery and humans. These characteristics explain why drains exhibited the highest brood use per mile of the three watercourse types.

Channel Management Practices

Several vegetation management programs currently used in irrigated areas should be subjected to close scrutiny via cost/benefit analysis. Spring burning, herbicide applications, and mechanical disturbance of soil along channels generally serve to exacerbate the problem of weed control rather than provide relief. These practices, as currently applied, are misguided in their aims to reduce weed pests. Rather than concentrating on target species or problem areas, treatments are often applied widely and indiscriminately, affecting all plant cover regardless of its level of beneficiality or noxiousness.

Ditch burning spreads beyond confines of channels to consume residual vegetation on banks above waterline and into adjacent idle areas. Wetlands bordering channels frequently are denuded either intentionally or through lax containment of fire.

Herbicide treatments seem to be a routine policy on watercourses, with actual need having little to do with the decision to spray or not to spray. Besides killing of nontarget plant species, sprayers make no attempts to confine toxic materials to land. Spray machinery with a long boom were seen several times spraying 5-foot-wide channel banks, while the remaining length of applicators dispensed chemicals directly into the water. Given the high cost of agricultural chemicals, irrigators could realize considerable savings by restricting herbicides to target species and definite problem spots.

Mechanical disturbance of soils on channel rights-of-way, while often necessary to maintain roads or clean out channel beds, has negative aspects. Grading, dredging, and tillage remove whatever vegetation cover exists, creating areas of bare mineral soil. Loss of soil-binding vegetation not only reduces wildlife habitat, but increases soil erosion and creates a competition-free seedbed for rapid growth and spread of undesirable plants. This in turn necessitates repeated, expensive control measures.

Livestock grazing, while not formally considered a management practice on channel rights-of-way, often promotes vegetation changes much like burning and spraying. And in extreme cases, the combination of grazing and trampling may reduce a site to bare soil, leading again to erosion and weed invasion. Because irrigation channels provide water, their rights-of-way suffer extremely intense use by livestock wherever grazing is permitted. Soil and plant community stabilities cannot be achieved until strict control of cattle use is achieved. As long as grazing goes unrestricted, right-of-way management costs to both irrigators and wildlife will remain higher than necessary.

Unrestricted burning, herbicide spraying, mechanical disturbance, and livestock grazing of many irrigation channel rights-of-way in the Columbia Basin reduce or preclude their use by wildlife and compound the problems of irrigators. A phytologic axiom states that whenever soils are bared, the first plant species to invade the site are usually economically undesirable. Furthermore, some weed pests, once established on a site, prove extremely difficult to eradicate. As a result, weed control costs rise, or at least cannot be reduced. In short, current vegetation management practices on rights-of-way represent stop-gap measures at best. More probably these practices actually promote the situations managers wish to avoid, ensuring an endless cycle of repetitive effort and expense.

Costs to irrigators can be substantially reduced if available knowledge of phytosociology is applied. By using the principles of natural plant succession, intense and discretionary vegetation plantings with followup management to ensure establishment and careful and conservative use of current practices both irrigation and wildlife interests benefit.

MANAGEMENT RECOMMENDATIONS

Design Features

Foremost in the design of irrigation watercourses should be the consideration of open channels, as opposed to buried or pipeline distribution systems.

Channels with concrete lining are of no value to waterfowl. Where seepage losses to the systems are excessive, the use of compacted earth, buried membrane, or parallel drains are more desirable corrective alternatives. The use of parallel drains on large canals and laterals appears the most desirable, for with parallel drains, a belt of undisturbed land is created between the main delivery channel and the drain which provides additional cover and habitat for ducks and other wildlife. From the irrigators' view, parallel drains recapture otherwise lost water, or at least reduce recovery expenses.

Although not addressed in the present report, meandering drain channels provide much more benefit to waterfowl for both the reproductive and nonreproductive seasons. It is suggested that wherever feasible, short stretches of channel be allowed to follow its own course.

Duck production and use could be increased in all irrigation channels by the creation of coves, such as exist in the East Low Canal, or by constructing ponds connected to the channel. For the latter, ideal locations would be at crossings of small natural drainage channels. A minimum of one cove for each mile of channel with dimensions similar to existing coves, or one pond per mile is recommended.

Drains and seep streams which have potential for year-round flows should be encouraged and protected for wildlife use. Minimum flows should also be established to protect habitat which develops in these channels.

Fish barriers should be installed in drains where necessary to prevent ingress by undesirable fish, primarily carp, whose bottom foraging habits increases turbidity which reduces photosynthesis and the production of submergent aquatic plant life. Downstream drop structures not less than 2 feet high and permeable instream barriers in the upper reaches would eliminate contamination from other waters.

Buffer strips of uncultivated land should flank the channel banks. Where spoil berms occur, the strips should flank the outside base; a minimum strip width of 30 feet is recommended. These strips would create, if left undistrubed, nesting sites and possibly year-round cover for many species of wildlife.

Channel Right-of-Way Management

Seep wetlands forming or existing near irrigation channels should be preserved for wildlife use, and grazing by livestock must be eliminated on these wetlands to attract breeding ducks.

Borrow areas and spoil piles should be covered with 3 to 6 inches of topsoil wherever possible. Vegetation plantings should be of species that are beneficial to wildlife yet present no weed problems to farming interests. Canal and drain banks offer tremendous potential to wildlife if management includes consideration for wildlife needs.

Traffic and other forms of mechanical disturbance have been identified as factors limiting waterfowl use of irrigation watercourses during the reproductive season. Therefore, vehicle traffic should be restricted to operation and maintenance crews during spring and summer. Maintenance roads should be limited to one side of watercourses.

Vegetation control programs and grazing practices should be evaluated for costs and benefits. Alternative programs may prove more economical and also beneficial to wildlife.

SUMMARY

Duck use on 229 miles of canals, laterals, and open drains in the Columbia Basin was studied during 1977-1979. Seventeen species of ducks were observed on the watercourses. Mallard, blue-winged teal, and cinnamon teal comprised 77 percent of the observations. Redhead ducks were the most common of the eight diving species identified.

Open drains, with their year-round flows, offered the only channeled waters available to ducks during the early part of the spring migration season. An average of 1.2 ducks per mile were observed on drains during this period.

During the latter part of migration, canals and laterals also contained water. The average number of ducks was estimated at 1.8 and 2.4 birds per mile, respectively. Drains, at this time, sustained about 4.9 ducks per mile. The late-spring migration period had the highest density of birds per mile on irrigation watercourses of any season.

Mallard, blue-winged and cinnamon teal, and redhead were the principal breeding species using channeled waterways. Duck use was estimated at 4.2 ducks per mile on drains, 2.0 per mile on laterals, and 1.2 per mile on canals. Duck numbers were highest during late July, but declined rapidly thereafter.

Duck use of irrigation channels dropped sharply following the reproductive season. Densities on drains and canals were 3.0 and 0.8 ducks per mile, respectively. Canals and laterals lack water from late fall through early spring.

Very little duck nesting occurred on channel banks; one nesting attempt per 10.6 miles of bank. Lack of nesting was believed a result of poor vegetation cover. Undesirable plant species, spring burning, herbicide treatments, and livestock grazing limited vegetation cover development on watercourse banks.

Except for diving species, watercourse size did not appear to be related to duck use. Divers were more numerous on large canals than on smaller drains and laterals. Flow velocities were low over all watercourses and were believed inconsequential to duck use. Concrete-lined channels were generally avoided by adult ducks; less than 1 percent of the total observations were on lined channels.

Broods of nine species were found on irrigation waterways. Some 417 different broods were counted in 3 years of study, with mallard and teal comprising 70 percent of the broods. Fifteen percent were redhead ducks. Densities of 1.6 duck broods per mile were noted for drains, 1.0 on canals, and 0.5 on laterals. Peak hatching occurred in mid-June with brood size averaging 4.8 ducklings.

Physical features as related to brood use were investigated on unlined canals, unlined laterals, and two drains. Four hundred brood sightings, including resightings, were used in the habitat use analysis.

Brood observations were related to bank type; broods used only reaches with earthfill banks that supported vegetation at the waterline. Shallow coves comprised only 21 percent of an unlined reach of one canal, yet supported as much as 55 percent of the broods seen on that reach.

Areas where broods were consistently seen along canals also had natural wetlands within 0.5 mile of the channel. About 50 percent of brood concentration areas were within 0.3 mile of adjacent wetlands.

Land use proximal to watercourses appeared to influence brood use. Duck brood observations were highest where undisturbed land bordered at least one side of the waterway.

Mechanical disturbance and human activity had a negative impact on brood use.

Based on low resighting frequencies and a strong association with adjacent wetlands, duck broods used irrigation channels primarily as travel lanes rather than for rearing. Resightings were higher on drains, suggesting that some broods may have been reared entirely on the drain.

Most laterals offered few of the habitat requirements of brood rearing. Insufficient water or severe flow fluctuations together with a relatively high amount of human disturbance were the factors responsible for low brood use. Laterals which service large areas usually have more stable flows, and normally sustain a moderate level of brood use.

Canals had water throughout the brood-rearing period, and flow levels were constant. Lack of aquatic vegetation and associated invertebrate animals severely limited food supplies for duck broods on canals and on laterals as well. Presence of coves and nearby natural wetlands were believed the most important reasons canals sustained as high brood use as was observed.

Drains were the most heavily used watercourse by duck broods. Most of the habitat requirements needed by young ducks were available, largely because of year-round water supplies. Drains also had the lowest amount of disturbance of the three water types.

A minimum estimate of 1,624 duck broods use open, unlined drains (excluding wasteways) and unlined canals and laterals of the Columbia Basin each summer. Few ducks nest on the banks of irrigation channels. Most nesting occurs in croplands and undisturbed uplands, often far removed from good brood-rearing wetlands. Under present design and management, irrigation watercourses serve waterfowl most importantly as travel lanes, providing transport for duck broods from nest sites to brooding areas.

Management practices which remove plant cover from unnecessarily large areas preclude use of channel rights-of-way by ducks for nesting and brood rearing. Other wildlife species sustain similar adverse effects, including loss of winter cover.

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CHAPTER II

MANAGEMENT IMPLICATIONS FOR WATERFOWL IN IRRIGATED AGRICULTURAL DEVELOPMENTS: LAKES, PONDS, MARSHES

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MANAGEMENT IMPLICATIONS FOR WATERFOWL IN IRRIGATED AGRICULTURAL DEVELOPMENTS: LAKES, PONDS, MARSHES

This chapter focuses on waterfowl use and production within and adjacent to Project static waters. Environmental factors and salient features of Project operation, farming practices, and wildlife management practices affecting waterfowl populations in the Columbia Basin are described. Objectives were as follows:

1. Determine the effects on waterfowl of several physical and biological features of lentic wetlands including:

    a. Limnologic/hydrologic characteristics;

    b. Aquatic vegetation distribution;

    c. Rough fish presence; and

    d. Nest predation;

2. Describe features relating to Project operation and their effects on waterfowl such as:

    a. Relationship of wetlands to irrigation watercourses;

    b. Wetland drainage; and

    c. Reservoir drawdowns;

3. Describe the effects of various farming practices (including farming on public lands) including:

    a. Groundwater pumping;

    b. Corn production; and

    c. Livestock grazing; and

4. Determine institutional and management impacts on waterfowl populations:

    a. Human disturbance;

    b. Wetland ownership patterns; and

    c. Wildlife management conflicts.

DESCRIPTION OF STUDY WATERS

Nearly all lakes and potholes selected for intensive study lie in or near the Columbia Basin Project area (fig. 2.1) and were strongly influenced by Project operation. Some waters are, at one time or another during the year, connected to Project drainage systems. Others, while presently isolated, have had direct connections to drainage channels in the past. Still other waters have remained isolated since their formation. All are influenced by seepage and most depend entirely on seepage for maintenance.

Basins of the 74 lakes and potholes which received intensive study occurred within two basic geologic formations: (1) channeled basalt scablands and (2) glacial outwash. Lakes of the former group (scabrock lakes) typically had basalt outcroppings bordering a portion or all of the basin. Generally, most had but a relatively narrow band of upland vegetation between shoreline and basalt cliffs. Presence of emergent aquatic plants varied from none on a few waters to extensive stands on others. Cattails and bulrushes represented the most common emergents, with sago pondweed and coontail as the most abundant submergent vascular species present.

Scabrock lakes ranged from 8 to 130 acres in size with maximum depths of 15 to 80 feet for those waters selected for study. Loessial and lacustrine deposits (marl and ooze) covered bedrock from a few inches to several feet in these lakes. The amount of littoral area varied markedly between scabrock waters.

Water chemistries indicated good fertility for a sample of the study waters. Fish life occurred in all but three lakes; one regularly dried up in mid-autumn, whereas the other two were extermely high in inorganic salts and therefor incapable of supporting fish.

Of the 22 scabrock lakes involved in the study, 50 percent were federally owned (U.S. Fish and Wildlife Service) and 32 percent were owned or managed by Washington Department of Game. Remaining waters (18 percent) were in private ownership. Lakes under Federal control were mostly on the Columbia National Wildlife Refuge. Recreational use (fishing) was particularly heavy from spring to early summer on nearly all the scabrock lakes.

Somewhat over 1,000 lakes, potholes, and other small wetlands in glacial outwash (hereafter collectively called flatland lakes) are located southwest of Moses Lakes, Washington, in an east to west trough. Topographic relief is generally low, with wide, relatively flat areas sandwiched between long, low (< 60-foot-high) ridges and mounds. Ground-water seepage and surface drains from higher farmlands to

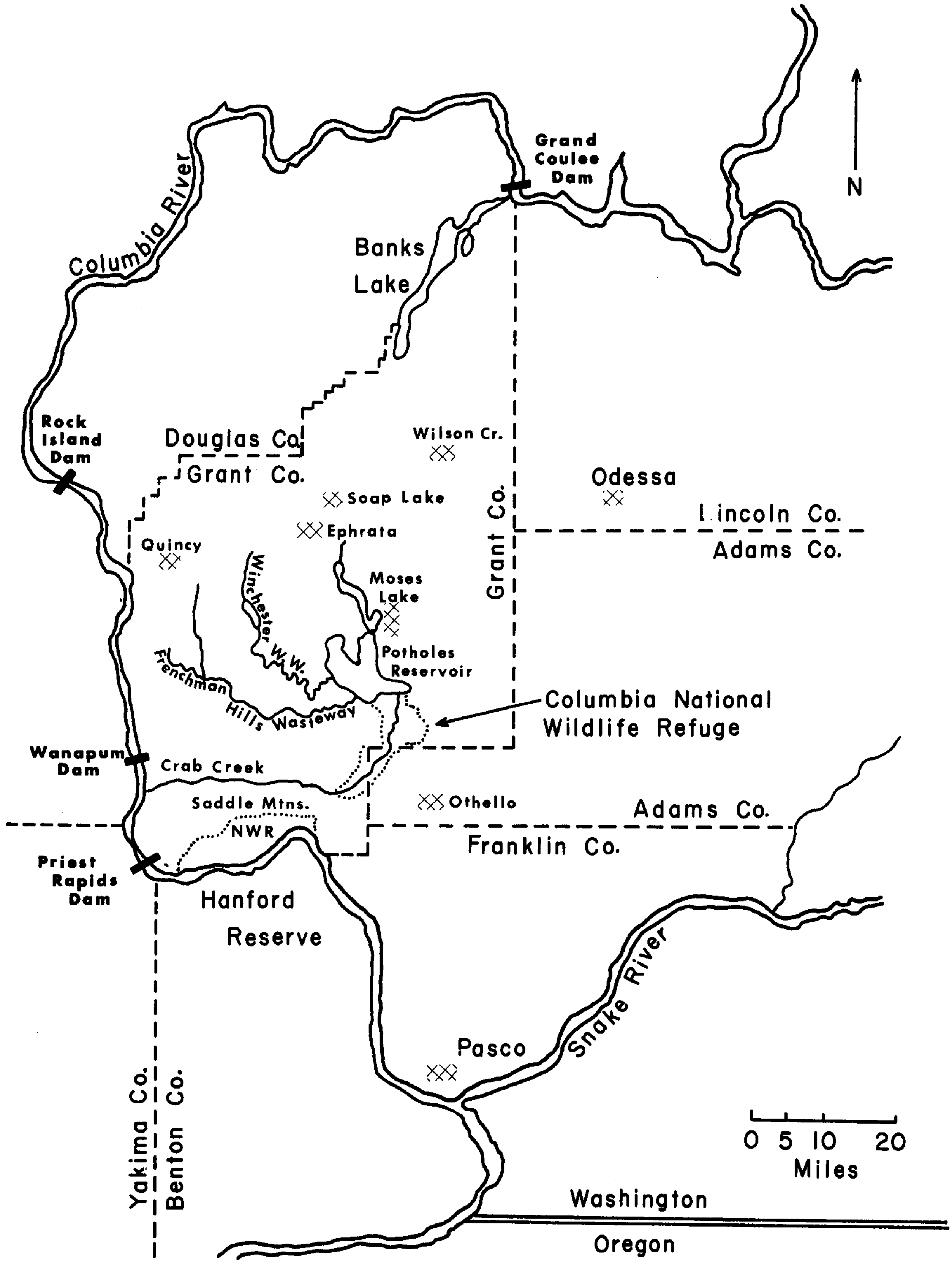

Figure 2.1.–Columbia Basin study area. The Columbia Basin Irrigation Project is contained within Grant and the western parts of Adams and Franklin Counties.

the north and west, and from Frenchman Hills which bounds the lowlands on the south, feed this wetland area. The area is blanketed by a mantle of gently undulating sand dunes, some of which constantly shift with prevailing southwesterly winds. Elsewhere, dunes appear to have been stabilized, at least temporarily, by shrubs and grasses. A large part of the area is underlain by caliche formations of varying thickness. Bretz (1959) [1] proposed that the sand originated from deposition by glacial melt waters which fanned out in the Quincy Basin of Grant County during the Pleistocene epoch.

Lakes, potholes, marshes, and wet meadows profusely dot the sand dunes area where most of the flatland class of study waters occur. Water levels reach maxima in February and March, then steadily shrink until fall. Drainage is both subterranean and surface, on a gradient sloping toward Potholes Reservoir which forms the east boundary of the sand dunes. Two surface drainages cut through the flatland lakes area, Frenchman Hills Wasteway, and the longer, anfractuous Winchester Wasteway. Both wasteways have been channelized in their upper reaches, but attain appearances of natural streams over the remainder of their routes. Many potholes and marshes are connected directly to these water courses.

A total of 52 flatland lakes comprised the sample from that class of waters, and varied in size from 0.1 to approximately 650 acres. Very few of the flatlands study waters exceed 20-foot-maximum depth. All were alkaline and had abundant littoral area. About 12 percent of the waters were temporary, drying up at least once during the study period.

Fish occurred in about 50 percent of the flatland lakes and potholes, primarily rainbow trout, large mouth bass, black crappie, yellow perch, and carp. Carp were the most common, and often the only fish species present in most waters. Remaining waters were devoid of fish life for a variety of causes: oxygen depletion in winter, high pH in summer, summer desiccation, or because fish had never been planted in the waters since they were formed.

A rich and abundant invertebrate fauna inhabited the flatlands lakes and marshes. Peak abundance coincided with spring migration of waterfowl. Cladocerans, copepods, corixids, and chironomids were the most conspicuous invertebrates, rendering the water column "alive" with their abundance. Amphipods and nymphal stages of ephemeropterans and odonates, foraging about in detritus and submerged plants, were less obvious to the casual observer, but nevertheless, comprised a significant part of total invertebrate biomass in both flatland and scabrock waters.

Vegetation around flatland study waters followed a pattern dictated by rapid changes in environmental gradients. An elevation change of 5 feet or less in sand dune and pothole topography may lead from rank riparian growth to semidesert plants. Harris (1952) [2] described vegetation of a dune-pothole area which has since been flooded by the formation of Potholes Reservoir. More recently, Fletcher (1979) [3] briefly discussed vegetation of the general study area and for various wetland types.

Plant species of importance to waterfowl for food and cover are generally abundant over most of the flatland lakes study area. However, prolonged and intensive cattle grazing in some areas has reduced or eliminated many of the desirable plants for waterfowl on uplands and around wetland margins. Likewise, carp foraging has severely reduced submerged aquatic flora wherever this fish occurs.

Common plants used extensively by waterfowl for food included muskgrass, coontail, watermilfoil, sago pondweed, and duckweed. Bulrushes, cattails, cheatgrass, and saltgrass formed protective and nesting cover. Several woody plants common to the flatland lakes area included willow, greasewood, big sagebrush, and rabbitbrush and were also used occasionally for nesting cover.

All other major bodies of water in the Columbia Basin were surveyed once each month to obtain a total count of Basin waterfowl populations. This group of waters included Columbia River impoundments, impoundments and natural lakes of the Grand Coulee, and the many scabland lakes and potholes lakes which were not included in the regular intensively studied waters.

METHODS

Fletcher (1979) [3] reported on 1976 and 1977 studies on waterfowl of Frenchman Hills and Winchester Wasteways systems. The present study included a sample of the same waters as well as wetlands from other parts of the Columbia Basin.

The lakes and ponds associated with Winchester and Frenchman Hills drainages are generally shallow with abundant littoral area. Since many static waters in the Basin occur in rocky, steep basins, often with limited littoral zones, limnologies differ somewhat from the wetlands associated with the two major wasteway systems. Selection of study waters was, therefore, based primarily on these elementary differences, with consideration given to other research objectives. Thus, choice of study waters was not entirely by random selection. Within practical limits, waters were selected from both categories (flatland

and scabrock types) which would yield fairly balanced samples for comparisons to meet study objectives.

The study waters were classed according to several characteristics believed to have significant effects on their use by waterfowl: (1) management authority; (2) wetland basin shape; (3) area; (4) wetland permanence; (5) agricultural use of shorelines; (6) presence of rough fish; and (7) season of public use.

Wetland control was classed as Federal, State, or private as shown by county auditor's maps.

Wetland basins were in either shallow, low-relief topography (flatland), or littorally impoverished, steepsided basalt formations (scabrock).

Areas of wetlands were obtained mostly from existing bathymetric maps or from aerial photos of known scale with the use of a compensating polar planimeter. An alidade and plane table were used to survey wetlands for which no records existed. All wetland acreages were determined from surveys made during late summer.

A wetland was considered temporary if devoid of standing water at any time during the year.

At least within the group of study waters, shoreline uses were either livestock grazing or unused (idle).

The presence or absence of carp was determined by one of three methods: (1) visual observation; (2) capture with nets or baited hooks; or (3) high water turbidity caused by foraging activities of the fish.

It was impractical to quantify public use on the intensive study waters; therefore, an indirect approach was used to determine disturbance impacts on waterfowl. First, study waters were classed as either sustaining public use or closed to the public throughout the year. Those open to public recreation were then categorized according to the months in which activities occurred.

Additional descriptive information collected for each wetland included:

1. Shoreline length;
2. Maximum water depth;
3. Water level fluctuations;
4. Presence of submergent vegetation; and
5. Percent of open water.

The sampling period was year round. Ground counts were made from April until freeze-up of most waters in late November. Thereafter, remaining ice-free waters were surveyed from aircraft until about 1 April. Ground counts of all waterfowl species were conducted every 7 to 14 days on the 74 intensive study waters. Counts were conducted from 0.5 hour before sunrise to 0900 hours and from 1500 hours to sunset. Observations were made from one or more vantage points for most wetlands. Where elevated viewpoints were unavailable, one or more observers skirted wetland perimeters to obtain full visual coverage of the wetland.

Duck brood counts included broody hens even though the brood was not seen (Hammond 1970) [4]. Brood counts were adjusted upward according to a species visibility factor developed during studies in 1976 and 1977 (Fletcher 1979) [3]. The number of ducklings in each duck brood was counted and age of each brood estimated (Gollop and Marshall 1954) [5] to allow backdating to hatching dates. Data for all waterfowl were grouped by season: spring, summer, and fall. The spring period ran from 1 April to about 20 June; summer work spanned late-June through August. Fall seasons covered the months of September, October, and November.

The results of summer waterfowl studies were analyzed separately for total waterfowl and for broods. This served to point out similarities as well as differences between factors which affect densities and habitat use for both waterfowl broods and the population as a whole.

Nest searches were conducted on several of the study waters, adjacent upland areas, croplands, and rights-of-way during the years 1976-1979. Nest searches were made in stands of emergent vegetation as well as upland vegetation. Three to five persons spaced approximately 5 feet apart searched the designated area for nests. The following information was recorded for each nest:

1. Species;
2. Number of eggs;
3. Nest status (active, hatched, deserted, destroyed, relic);
4. Nest predator (mammal, bird, unknown);
5. Vegetation at nest; and
6. Distance from open water.

Waterfowl counts on the 74 study waters were summed by season. Seasonal totals were divided by the number of survey trips made during each respective season. This average was considered an estimate of daily waterfowl numbers using the wetlands throughout a given season. Variations in duck and goose densities were common for the study waters from one survey to the next; however, the trend within a season was usually consistent from beginning to end.

Statistical treatments were limited to regression analysis and chi-square tests. Although effects of various conditions on waterfowl are likely to be interactive, we saw no practical need to perform tests of interaction for the purposes of these studies.

RESULTS

Spring and Summer Seasons

Migrations, Populations, and Concentration Areas

When spring migration commences, waterfowl find fairly abundant habitat for resting and feeding as they move north to or through the Columbia Basin. Water in lakes, potholes, and streams throughout the area approach maximum levels soon after spring thaws. Thousands of temporary ponds, marshes, and wet meadows are filled with snowmelt and rainwater. Streams overflow natural channels, flooding pastures and occasionally wheatlands within the floodplain. When ducks arrive, food is abundant: thousands of acres of shallow water covering grain residue and the seedfall of last summer's resident flora. A few successive days of warm temperatures in late-February and early-March spur reproduction in aquatic invertebrates, further adding to the fare of several hundred thousand migrating ducks and geese.

Although mallards are generally regarded as the earliest migrating species in spring (Bellrose 1976) [6], it is difficult to determine when migration of this species begins in the Columbia Basin since wintering populations number several hundred thousand. A temporary exodus of wintering ducks from Grant County in the northern part of the Columbia Basin Project correlates with freeze-up. But as soon as open water returns, ducks swarm back. Freeze-up may occur at any time after early-November, lasting from a few days to 2 months. Furthermore, freezing and thawing may occur several times during a winter. This on and off pattern of icing creates a see-sawing of wintering duck populations between northern and southern parts of the Project until spring iceout. Such confusion taxes conventional methods of establishing migration onset in mallards. Therefore, since very few pintails winter in the Basin, the first appearance of large flocks of this species is generally regarded as the beginning of migration. Monthly aerial counts from 1975 through 1977 indicated the peak of migration occurs between mid-February and mid-March (fig. 2.2). By May, total waterfowl counts averaged less than 10,000 indicating the migration was largely past.

During mid-summer, waterfowl numbers reach their lowest levels. Figure 2.3 shows results of aerial surveys of waterfowl in the Columbia Basin during summer. Observable ducks tallied from 5,100 to 7,500 during July 1975-1977, the lowest month of the year. July counts probably underestimated actual numbers of waterfowl. Dense vegetation growth, hens still on their nests, and secretive habits of young puddle duck broods were the most likely cause of estimation error. The degree of error is unknown but is believed to be higher than at other seasons of the year. Geese numbers in July appeared relatively constant over the three years at about 2,400 birds (fig. 2.3). August counts exceeded 48,000 birds in the Columbia Basin in 1975 but fell below this in 1976 and 1977 to an average of 26,000. Still this was a marked increase over July counts.

High numbers of ducks in August and early September have generally been attributed to local production and influx of young and adult birds from drying potholes of Douglas and Lincoln Counties. However, these assumptions have not been tested.

From February on, spring counts generally reflected a continuum of passing waterfowl which seldom stayed in the Basin more than a few days. Several areas were identified which were used heavily by migrating birds. Grant County was the focus of most activity, but a few areas in Adams County showed appreciable spring use also. Upper Crab Creek between the towns of Odessa and Stratford was a staging area for Taverner's Canada geese and several species of ducks as they prepared to head north. Highest numbers occurred in February and early March; by late March the birds were gone. Peak counts of over 26,000 geese, 22,000 ducks, and 1,000 swans were made on this reach over the 5 years of this study. About 40 percent of use was confined to flooded wheat, alfalfa, and pasture lands on the Crab Creek floodplain from Marlin downstream to the town of Wilson Creek.

The wetland complex of Frenchman Hills and Winchester Wasteways, the northern dunes area of Potholes Reservoir, the Hanford and Wanapum reaches of the Columbia River, Caliche and Cabin Lakes areas west of George, Stratford, and Round Lakes (mainly geese), and the Columbia National Wildlife Refuge seemed to attract the most waterfowl during spring migrations. Crab Creek below

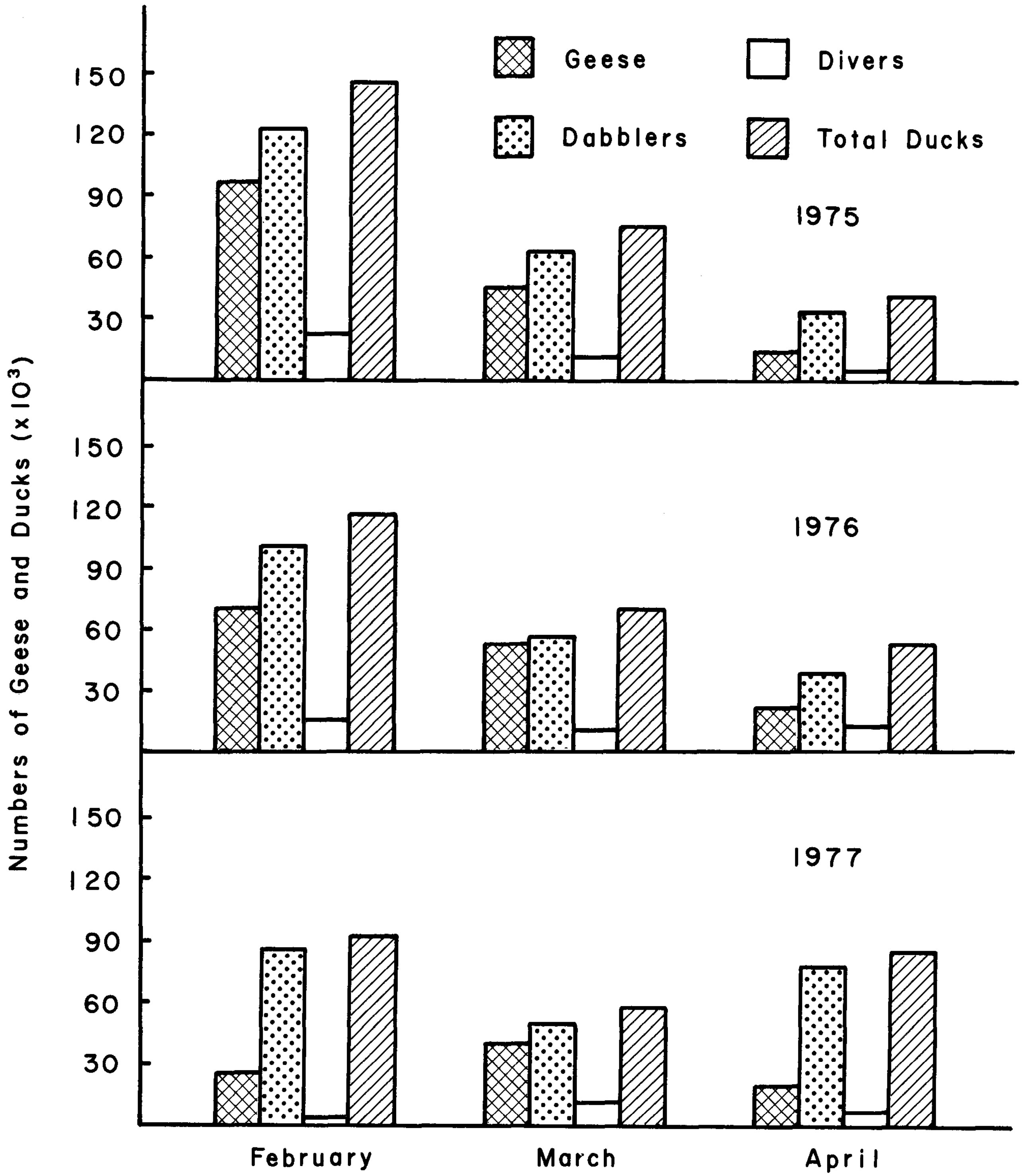

Figure 2.2.–Number of geese and ducks counted during early spring on all waters of the Columbia Basin, excluding the Columbia and Snake Rivers confluence and the Columbia River upstream from Rock Island Dam, 1975-1977.

Corfu also attracted many birds, although present use was far below that of 15 years ago. Years of unrestricted cattle grazing has devastated vegetation and stream channels along this reach.

During summer, virtually every wet area in the Columbia Basin from streams to sewage treatment lagoons attracted waterfowl. Often for reasons perhaps clear only to the birds, some waters were used continuously and by relatively large numbers of waterfowl, while other waters were visited only momentarily at rare intervals.

Nonbreeders and postbreeding drakes banded together in groups of 5 to 100 or more birds and

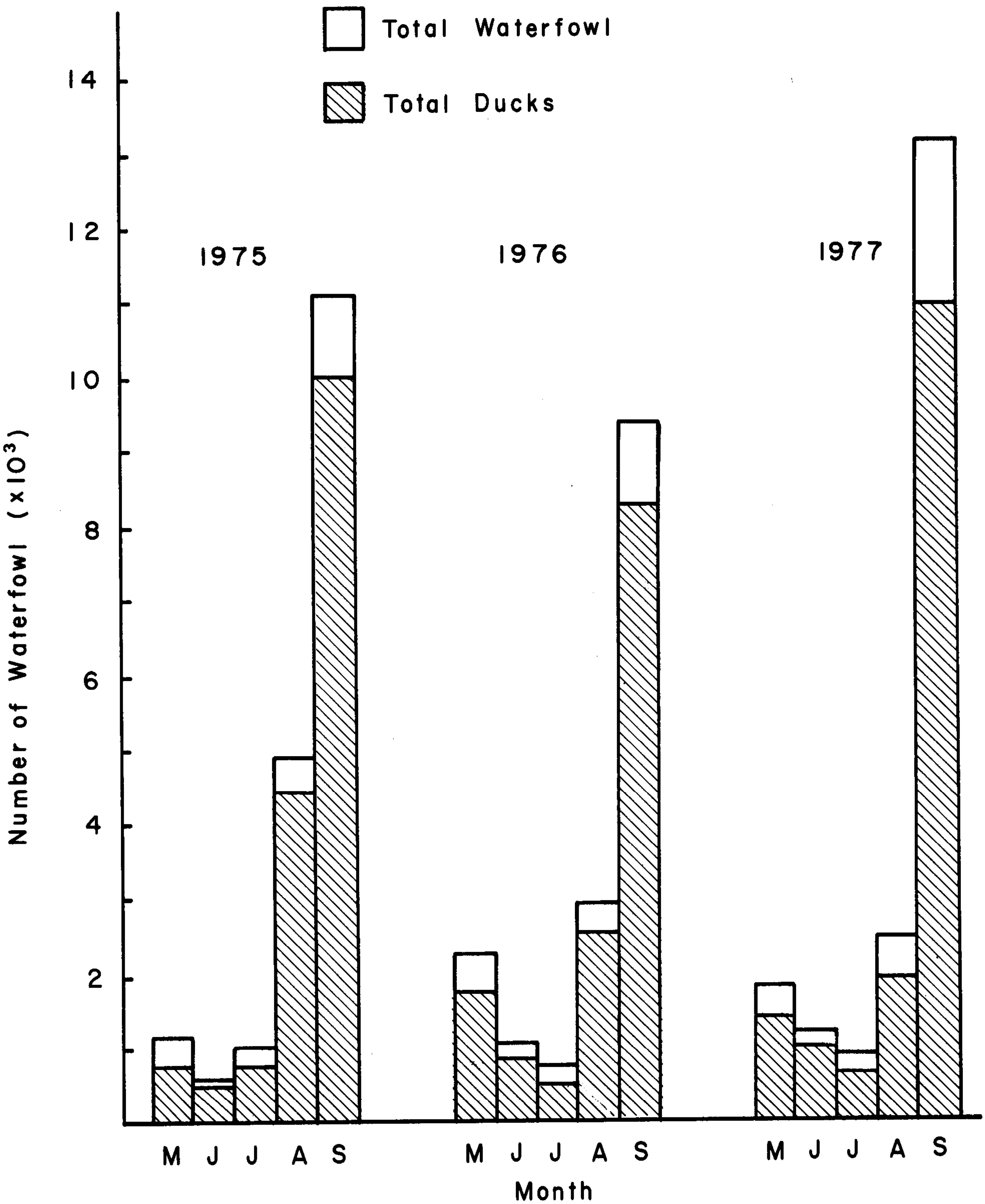

Figure 2.3.–Total number of waterfowl by month during late spring and summer in the Columbia Basin, Washington. Counts were made from aircraft on all waters except the Columbia River upstream from Rock Island Dam and the confluence of the Snake and Columbia Rivers.

generally appeared to wander throughout the Basin in early summer. Molting drakes were most frequently observed on large, shallow waterbodies. Intermingling of species was common. Frenchman Hills Lake, the sand dunes wetlands of northern Potholes Reservoir, Moses Lake, lakes within Unit I of Columbia National Wildlife Refuge, the seep lakes on the north rim of lower Crab Creek Coulee, and a few waters in Scooteney-Eagle Lakes area seemed to support the most consistent use by nonbreeders and molting drakes. In general, large, shallow waters with abundant emergent plants for cover were most heavily used. However, remote, small wetlands where disturbance was minimal were also used heavily.

Hens attending young were distributed throughout the Basin on all water types. The single most important area for brood rearing was the Frenchman Hills-Winchester Wasteways complex. Fletcher (1979) [3] estimated a minimum production of over 6,200 ducklings in this area in 1977 and 5,700 in 1976.

During early years of the present study, the north segment of Potholes Reservoir was only lightly used for brood rearing. Most summer use was by nonbreeding and molting ducks. However, after 1978, production increased considerably for both ducks and geese and the North Potholes area is presently considered one of the most important production areas in the Basin. Recent management changes have stimulated this: public access restrictions, carp removal, and reduction in livestock grazing.

Moses Lake also provides good habitat for many breeding ducks. The many streams, ponds, and lakes of the Columbia National Wildlife Refuge rates near the top in brooding duck use. As will be discussed later, production and use was not equally distributed among waters on the refuge. But then this was not unique to the refuge as several of the intensive study waters outside the refuge boundaries showed similar characteristics. Variations in summer duck use occurred between years on the same waters and among waters within years.

Canada geese were more consistent, returning yearly to the same waters to raise goslings. Prior to this study the extent of goose use on the wasteways of the Project was unknown. Approximately 10 percent of the summering goose population in the Columbia Basin resides largely on Frenchman and Winchester Wasteways. The largest segment of the population uses the Columbia River, with the free-flowing stretch near Hanford Atomic Energy Reservation most heavily used. Hanson and Eberhardt (1971) [7] estimated 200 breeding pairs and 150 unemployed geese used the area throughout the summer. Moses Lake, Potholes Reservoir, North Potholes, and Banks Lake round out the major waters for geese in the Basin.

Factors Affecting Spring and Summer Populations

Certain factors were tested during this study to determine why some wetlands were used more than others. The following sections discuss those variables which were found to be most influential on waterfowl distribution and use in the Basin.

Wetland Ownership

Land ownership is of no interest to waterfowl, whose concerns are abundance of food, protective cover, freedom from disturbance, and companionship of others of their own or similar phylogenies. Likewise, wetland ownership has no particular significance to the waterfowl manager so long as the species requirements are met and a harvestable surplus can be produced. Comparisons between waterfowl use on wetlands of varied title do act somewhat as indicators of possible physical or management constraints which reduce a wetland's potential for waterfowl use.

On intensively studied waters, more ducks were observed per survey day in spring on State-owned or managed wetlands than on either Federal or private waters (table 2.1). The relationship was even more pronounced for the summer period.

Waterfowl populations in the Columbia Basin tend to disperse over more waters after late winter thaws. However, distributions become greater following the end of hunting season in January. Many waters seldom hold more than a handful of ducks during winter even though they may remain free of ice. But as warmer weather arrives, more and more of the wetlands are used, sometimes by large numbers of ducks. A further boost in the occupancy of wetlands ensues with the arrival of migrants in February and March from the southern end of the Pacific Flyway.

This pattern of redistribution is reflected in figure 2.4 for State habitat management areas and streams which often sustained very low use by waterfowl during winter. Waters on State-owned lands received greatest use by waterfowl during winter-spring and summer-fall transitions. Canada geese exhibited the same trend of spring build-up on State-owned waters as did ducks.

Figure 2.5 reveals a different pattern of spring duck use on waters under Federal Government ownership. These waters comprised Columbia and Saddle

Table 2.1.—*Average daily waterfowl counts by season (1978, 1979 combined) for wetlands under three different ownerships in the Columbia Basin, Washington*

Species	State			Federal			Private		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Whistling swan	9.0	0.0	0.0	22.0	0.0	11.6	0.0	0.0	10.2
Canada goose	718.0	119.8	21.4	7,581.5	6.6	2,596.6	688.5	11.8	133.0
Mallard	2,898.5	410.6	15,191.4	1,081.0	57.0	22,249.6	894.5	35.6	151.4
Gadwall	40.5	95.8	58.4	13.5	11.2	33.6	21.5	9.8	12.2
Wigeon	248.5	26.0	515.4	221.0	2.4	359.8	8.0	4.8	8.6
Pintail	2,210.5	30.0	1,248.6	84.0	2.0	1,829.6	196.5	2.8	12.0
Green-winged teal	55.5	6.8	630.0	26.5	0.6	203.8	46.0	2.4	5.0
Blue-winged/ cinnamon teal	9.0	159.2	41.4	0.0	33.6	1.8	5.0	15.6	6.4
Shoveler	47.5	32.2	0.0	9.5	0.2	1.4	3.0	1.4	1.4
Redhead	96.5	199.2	90.2	34.5	19.0	28.4	52.0	12.0	7.6
Ring-necked duck	2.0	0.0	1.2	8.5	8.0	8.0	3.0	0.0	0.0
Canvasback	33.0	2.6	2.2	33.0	0.4	6.6	2.0	3.0	16.0
Lesser scaup	8.0	16.6	3.4	28.0	3.4	73.0	2.0	0.8	23.0
Barrow's goldeneye	52.5	0.0	3.2	48.5	1.6	0.0	42.0	0.0	0.0
Bufflehead	2.0	3.0	3.6	57.5	2.2	5.8	1.0	0.8	4.8
Ruddy duck	14.5	108.2	41.6	49.0	20.2	3.0	3.0	14.6	1.2
Hooded merganser	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Common merganser	3.0	0.0	0.4	7.0	1.2	25.0	0.0	0.8	1.4
Total dabblers	5,170.2	760.6	17,633.4	1,436.0	107.0	24,577.8	1,174.5	72.4	197.0
Total divers	209.0	329.6	145.8	266.0	56.0	149.8	105.0	32.0	55.2
Total ducks	5,379.2	1,090.2	17,779.2	1,702.0	163.0	24,727.6	1,279.5	104.4	252.2
Mean densities[a] per:									
acre	3.9	0.8	12.9	3.8	0.4	70.9	3.1	0.3	0.7
1,000-ft shoreline	20.3	4.1	67.7	14.2	1.4	204.7	16.9	1.6	3.9

[a] Ducks only.

Mountain National Wildlife Refuges and received greatest duck use during winter. Springtime revealed a large exodus of ducks from Federal wetlands, apparently opting for many waters on State lands.

Nearly all State and private wetlands are open to hunting. Those which remain free of ice experience constant hunting pressure. It is largely this pressure that causes waterfowl to concentrate on the refuges of Federal wetlands. After the hunting season ends in January, birds disperse from the refuges to the generally higher quality habitat of flatland waters which are mostly under State control (figs. 2.4 and 2.5).

Geese appeared less inclined to leave Federal refuge lands near the end of winter. January and February populations were roughly similar between 1975 and 1976. Variation between January and February counts for 1977 reflect weather and feeding patterns of the geese (fig. 2.6). Geese were only loosely associated with refuge waters is late January and

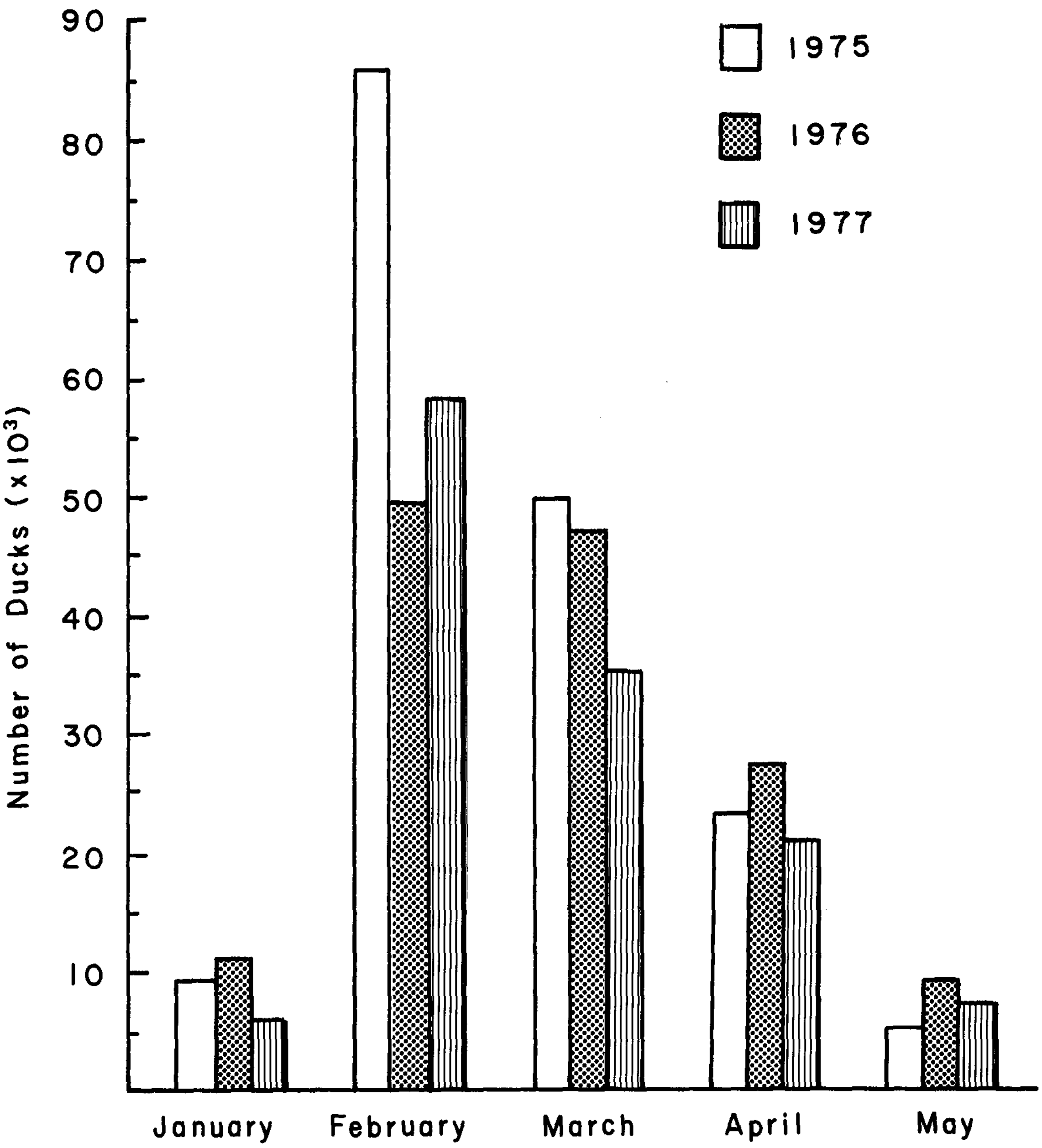

Figure 2.4.–Total monthly duck counts on State habitat management areas and streams in the Columbia Basin, Washington, showing changes in abundance by month, 1975-1977.

February. Birds generally sought out upland areas, grazing on young cheatgrass which renews growth in January after the usual warming trend. Maximum temperature remained near freezing or below during most of January 1977, delaying growth of cheatgrass. At the time of the survey in mid-January, cheatgrass had not renewed growth and therefore did not attract geese to Federal lands.

Waterfowl counts during summer surveys revealed a decided preference for State wetlands by ducks (table 2.1, fig. 2.7). Factors relating to wetland basin type and public use accounted for this preference over Federal waters. These aspects will be discussed in following sections.

Wetland Basin Type

Densities of ducks during spring and summer periods were significantly higher on waters in what has previously been described as "flatland" areas than on scabrock lakes (table 2.2). Because of low topographic relief, basins in these areas lacked precipitous slopes and normally provide abundant littoral area for food production. Many of these waters were devoid of fish life which may compete with ducks for

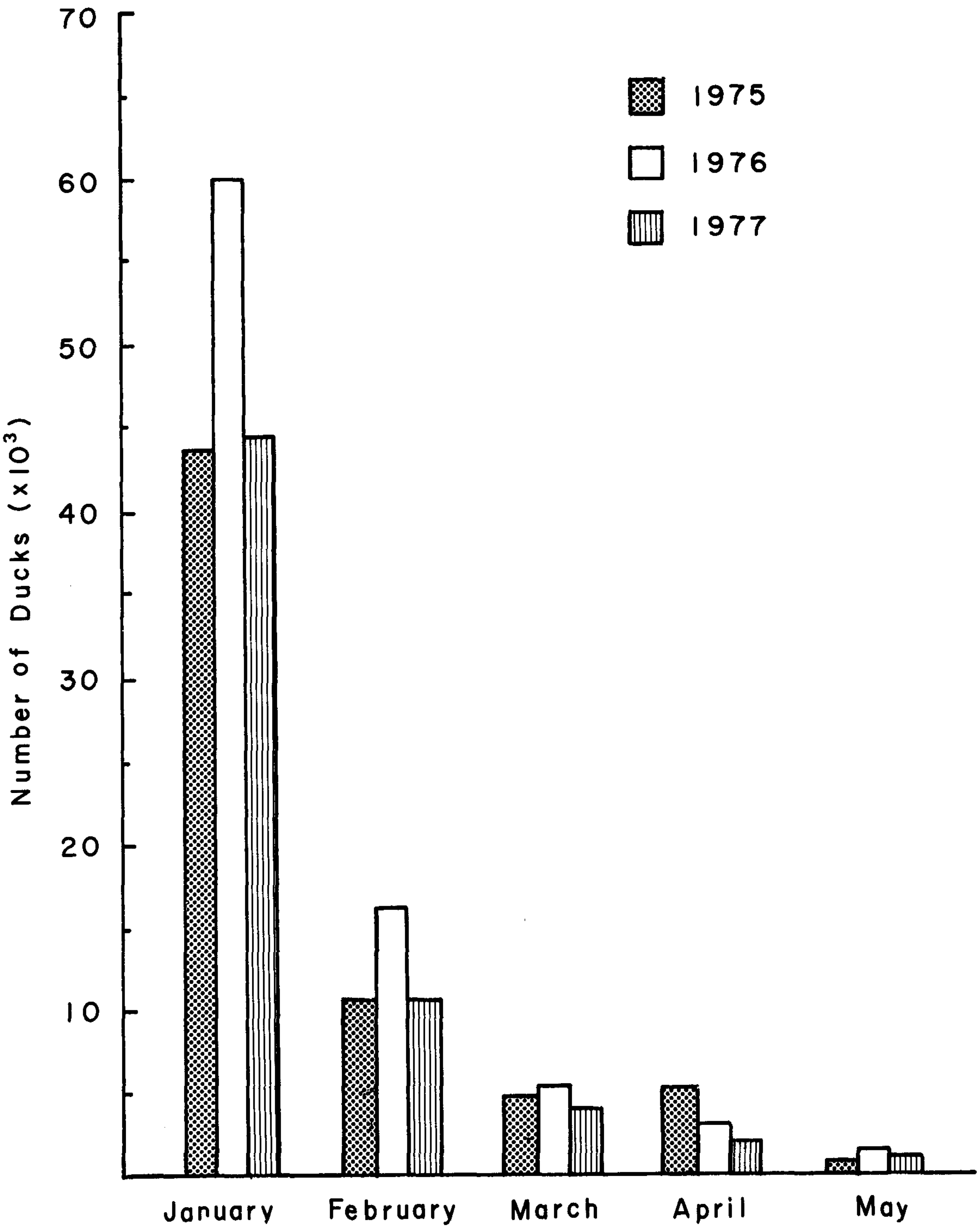

Figure 2.5.-Total monthly duck counts on Columbia and Saddle Mountains National Wildlife Refuges in the Columbia Basin, showing changes in abundance by month, 1975-1977.

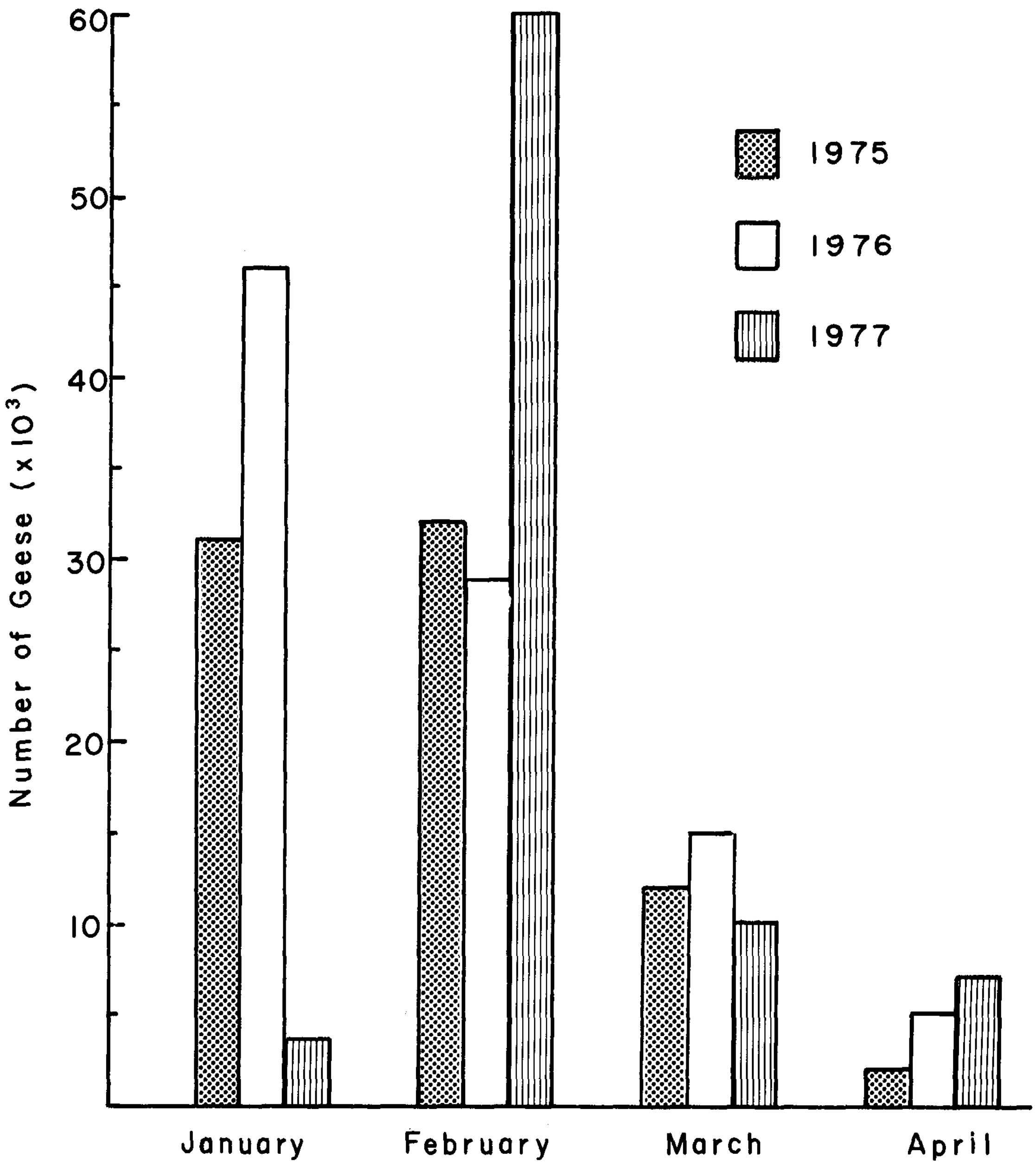

Figure 2.6.–Total monthly counts of Canada geese on Columbia and Saddle Mountains National Wildlife Refuges, showing changes in abundance by month, 1975-1977.

certain foods or, as with carp, create constant turbidity which reduces photosynthetic action. This and other factors affecting duck use of flatland basins are discussed in later sections.

Surface Area

Wetland size has often been ascribed as an important characteristic for waterfowl nesting and brood rearing (Berg 1956 [8], Drewein, and Springer 1969 [9], Smith 1971 [10], Stoudt 1971 [11]). In the Columbia Basin, spring migrants showed no particular orders of use based on wetland size for the seven size classes tested (fig. 2.8). The type of wetland basin seemed to be more important than size class. However, later in spring when pairs began to nest or search out nesting areas, small wetlands (< 5 acres) appeared to be used more heavily. Evans and Black (1956) [12], using smaller size class divisions, documented similar "preferences" by breeding pairs. They found greatest densities on South Dakota ponds less than 0.3 acre in size, but breeding pair use remained relatively high up to about 5 acres.

General waterfowl use of intensive study waters during summer declined with increasing wetland surface area. Densities were highest (5.6 ducks per acre) on wetlands up to 1.0 acre in size. Waterfowl

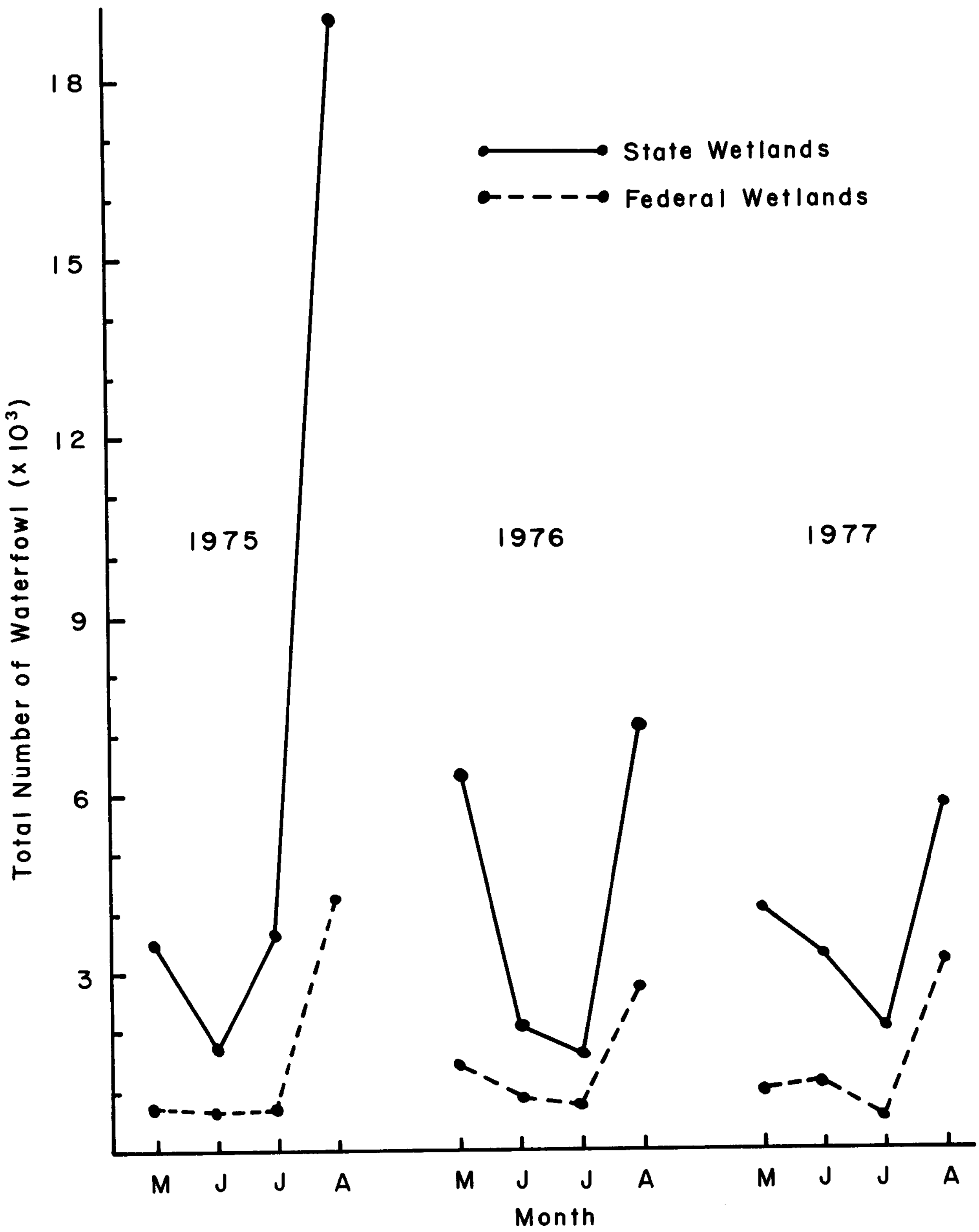

Figure 2.7.–Waterfowl counts on Federal refuges and State habitat management areas by month for summers, 1975-1977. Counts were made from aircraft.

Table 2.2.—*Average daily waterfowl counts by season (1978, 1979 combined) for wetland basins within two different geologic settings in the Columbia Basin, Washington*

Species	Scabrock type			Flatland type		
	Spring	Summer	Fall	Spring	Summer	Fall
Whistling swan	28.0	0.0	21.8	3.0	0.0	0.0
Canada goose	8,101.0	19.4	2,729.8	887.0	118.2	21.2
Mallard	1,928.0	112.6	22,388.2	2,946.0	390.6	15,204.2
Gadwall	25.5	26.2	42.0	50.0	90.6	62.2
Wigeon	287.5	7.4	420.8	190.0	26.8	463.0
Pintail	184.0	3.4	2,079.6	2,307.0	31.4	1,010.6
Green-winged teal	47.5	1.0	227.0	80.5	8.8	611.8
Blue-winged/ cinnamon teal	2.0	58.0	35.8	12.0	150.0	13.8
Shoveler	20.5	4.2	1.4	39.5	29.6	1.4
Redhead	111.5	53.2	73.6	71.5	177.0	52.6
Ring-necked duck	10.5	8.0	8.4	3.0	0.0	0.8
Canvasback	58.5	0.4	24.8	9.5	5.6	0.0
Lesser scaup	28.0	5.6	96.4	10.0	15.2	3.0
Barrow's goldeneye	141.0	1.6	3.2	2.0	0.0	0.0
Bufflehead	58.5	3.0	14.2	2.0	3.0	0.0
Ruddy duck	61.0	50.6	43.0	5.5	91.4	2.8
Hooded merganser	0.0	0.0	1.2	0.0	0.0	0.0
Common merganser	7.0	2.0	26.8	3.0	0.0	0.0
Total dabblers	2,499.0	212.8	25,314.2	5,310.0	727.8	17,474.6
Total divers	476.0	124.4	343.0	104.0	293.2	59.6
Total ducks	2,975.0	337.2	25,657.2	5,414.0	1,021.0	17,534.2
Mean densities[a] per:						
acre	2.8	0.3	25.6	4.7	0.9	15.0
1,000-ft shoreline	11.6	1.4	105.2	26.4	5.0	86.1

[a] Ducks only.

densities declined less rapidly on waters greater than 5 acres (fig. 2.8). These observations parallel findings of Evans and Black (1956) [12] who also noted greatest densities of ducks in summer on wetlands of less than 5 acres.

The relationship between wetland size and waterfowl numbers was nonlinear; best fit of the data ($r^2 = 0.70$) was obtained with a power curve function (fig. 2.9, Brownlee 1965) [13].

Water Level Fluctuations and Permanence

Lakes and ponds within scabrock areas of the Columbia Basin Project were all permanent. Fluctuations in water levels did occur every year but, because of relatively steep perimeters, surface area did not change drastically.

Desiccation of wetlands with the flatland areas were relatively few (6 of 50 waters). Periods of dryness varied between study waters. One small wetland contained water throughout 1976 but was dry from summer 1978 through summer 1979. Three others were dry only during the fall of 1978. The remaining two were dry during spring and/or summer 1979 yet maintained water during 1978, a drought year. Differences in waterfowl use between temporary and permanent waters could not be readily supported by statistical tests because of too few temporary waters in the sample.

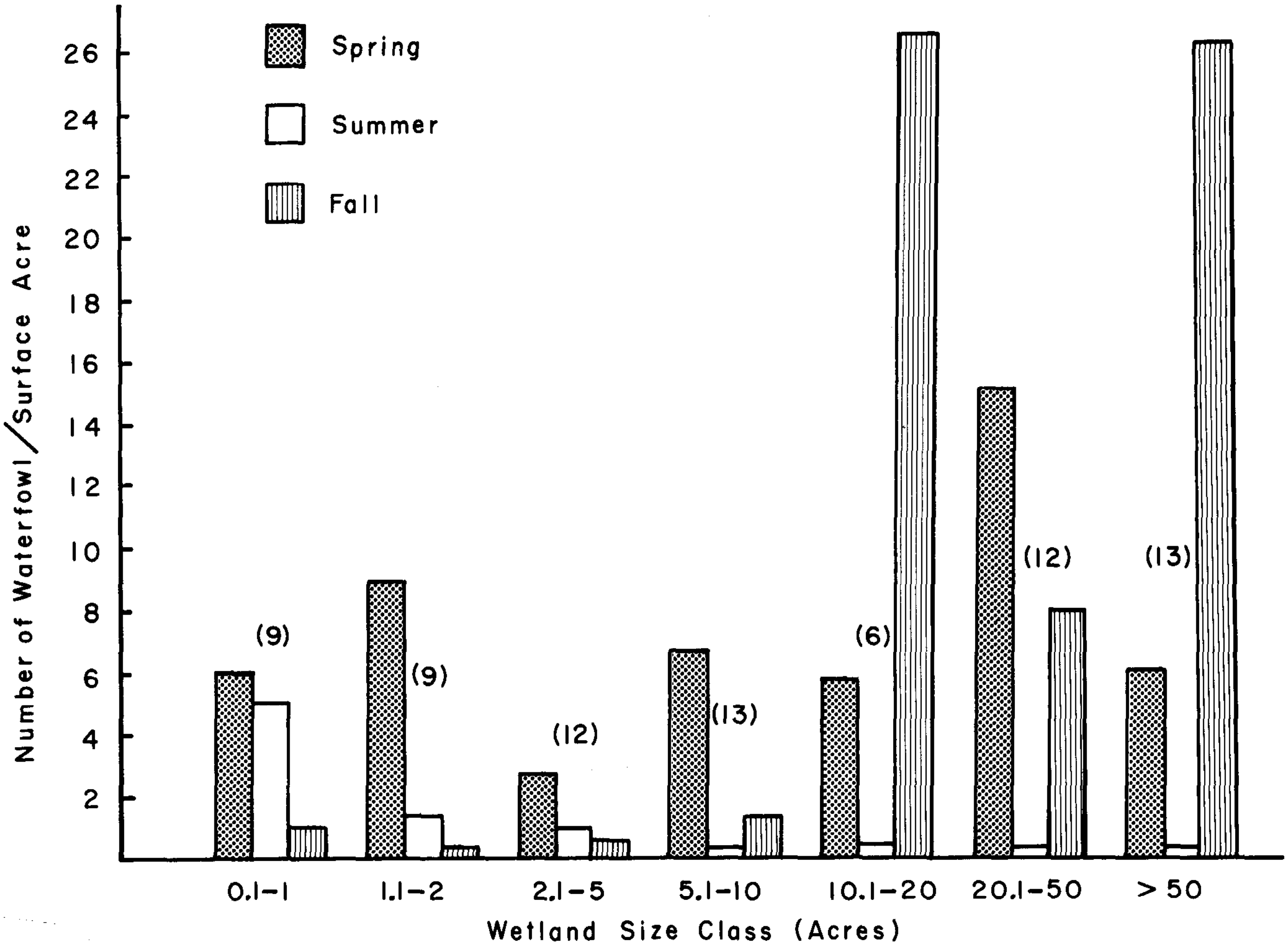

Figure 2.8.–Mean number of waterfowl observed per survey on 74 study waters classed by surface area. Data for 1978 and 1979 are combined and reflect differences by season in the Columbia Basin, Washington. Numbers in parentheses are the number of wetlands sampled for each size class.

More notable was the fluctuation in water levels in flatland areas. Decreases in water levels have approached 2 feet on these waters between April and July (Foster and Tillett 1977) [14]. However, declines were most severe during summer and, consequently, had little impact on early- to mid-spring use by ducks.

Of significance to summering ducks was the noted decrease in surface waters of the Winchester-Frenchman Hills wetlands. Many ponds and marshes lost as much as 75 percent of their surface area between spring and late-summer. Quite a few marshes dry up completely during summer more than were indicated by the sample of intensive study waters. Foster and Tillett (1977) [14] reported on initial results of monitoring 13 wetlands in the Winchester Wasteway area. Their data suggested a general decline in surface water levels between 1976 and 1977. Additional data collected after 1977 (presented in the fisheries section) confirmed that surface levels showed a general decline throughout the 5 years of this study. Unfortunately, wetlands have not been adequately mapped for yielding comparisons of surface area between early and recent years of Project operation. Thus, no reference points exist from which to gage influences on summer waterfowl use.

Livestock Grazing

Shorelines of waters selected for study were either unused (idle) or grazed by livestock. Both spring and summer duck use on idle shorelines were higher than on those which were grazed (table 2.3).

The problem of trampling and overgrazing of shoreline vegetation is both widespread and harmful to waterfowl management. Many investigators have shown that the removal of shoreline and upland vegetation severely limits the attractiveness of an area during the reproductive season (Salyer 1962 [15], Burgess *et. al.* 1965 [16], Martz 1967 [17], Drewien 1968 [18], Kirsch 1969 [19],

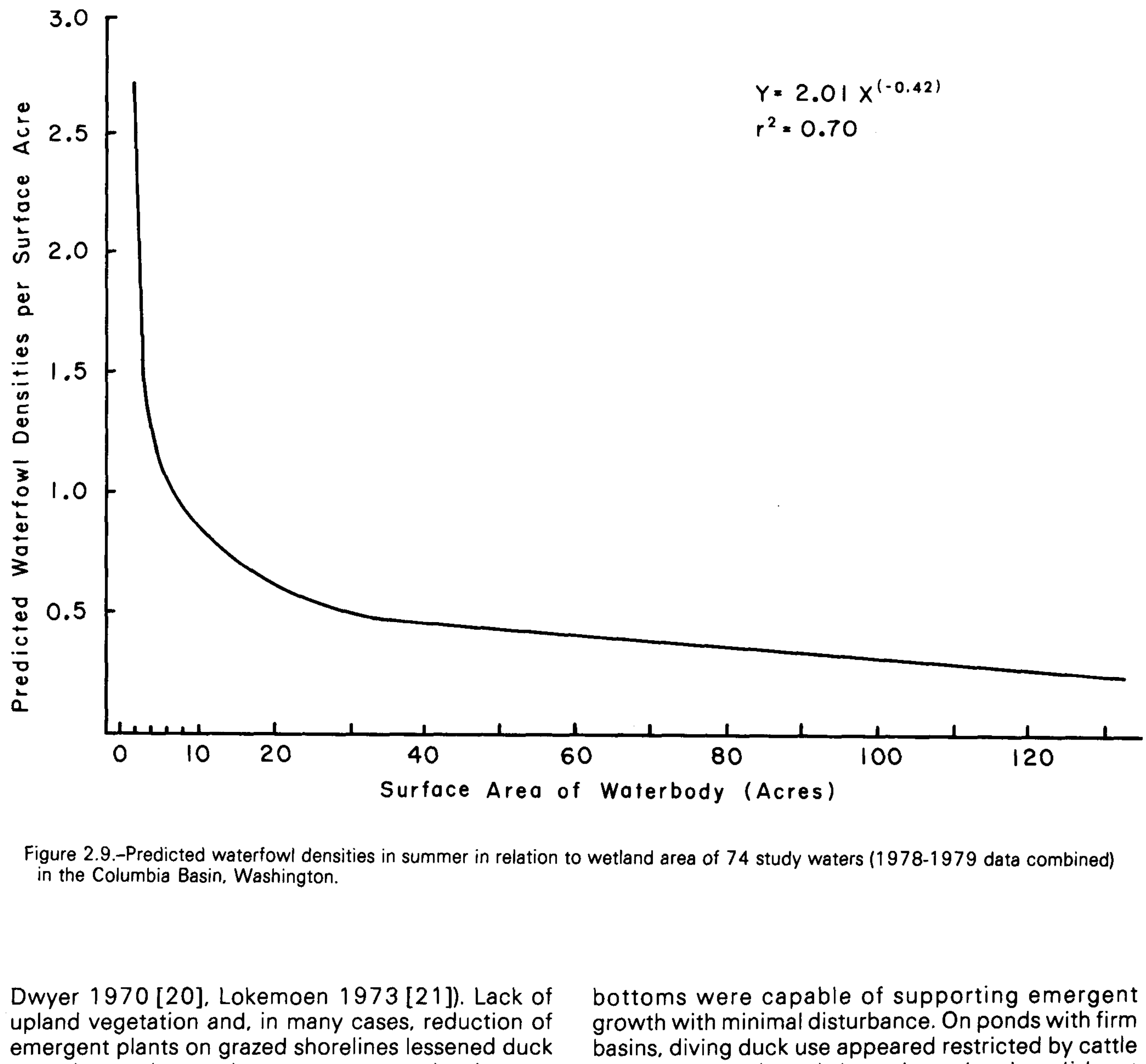

Figure 2.9.–Predicted waterfowl densities in summer in relation to wetland area of 74 study waters (1978-1979 data combined) in the Columbia Basin, Washington.

Dwyer 1970 [20], Lokemoen 1973 [21]). Lack of upland vegetation and, in many cases, reduction of emergent plants on grazed shorelines lessened duck use throughout the present study. Logan (1974) [22] found that cattle grazing had a negative effect on aquatic plant communities in Oklahoma studies. However, he noted the effect seemed to be dependent on pond area (with small ponds impacted most severely) rather than cattle stocking rates. Similar observations were made in the present study. Small wetlands (< 5 acres) were generally shallow and subject to large fluctuations in water levels. As a result, livestock grazed more heavily on newly emergent plants, particularly cattails and bulrush of small wetlands than of wetlands greater than 5 acres in size.

There were many exceptions to this observation, however. Whenever wetland substrates were composed of deep muck, cattle avoided the shallow shoreline areas. Thus, small ponds with unstable bottoms were capable of supporting emergent growth with minimal disturbance. On ponds with firm basins, diving duck use appeared restricted by cattle grazing even though brood production did not require upland vegetation. For divers, which generally nest over water in emergent growth, grazing effects were compounded by the summer drop in water levels. This lower water level opened up more emergent stands to cattle use and thereby limited potential nest sites, especially during early nesting attempts when nests were often constructed in the extreme shallows. As a result, fewer diving ducks used shallow ponds where cattle had grazed than on ungrazed wetlands.

Cattle grazing was a decided advantage to geese which prefer the close-cropped pastures left by cattle. This was not applicable to all wetlands. Geese were found only where nesting habitat was available in the form of islands generally on large bodies of water. Only a very small number of the 74 intensive

Table 2.3.—*Average daily waterfowl counts by season (1978, 1979 combined) for wetlands under two different shoreline use patterns in the Columbia Basin, Washington*

Species	Idle			Grazed		
	Spring	Summer	Fall	Spring	Summer	Fall
Whistling swan	16.0	0.0	11.6	15.0	0.0	10.2
Canada goose	1,225.5	129.2	348.8	7,762.0	8.4	2,402.2
Mallard	3,512.5	431.6	21,073.4	1,361.5	71.6	16,519.0
Gadwall	40.5	82.2	78.8	35.0	34.6	25.4
Wigeon	443.5	32.6	684.4	34.0	1.6	199.4
Pintail	2,224.5	33.6	2,418.6	266.5	2.2	671.6
Green-winged teal	94.0	7.4	627.6	34.0	2.4	211.2
Blue-winged/ cinnamon teal	7.0	145.4	43.0	7.0	62.6	6.6
Shoveler	55.0	30.4	2.8	5.0	3.4	0.0
Redhead	81.0	170.6	85.4	102.0	59.6	40.8
Ring-necked duck	3.0	8.0	8.0	10.5	0.0	1.2
Canvasback	24.5	1.0	6.6	43.5	5.0	18.2
Lesser scaup	32.0	18.2	73.4	6.0	2.6	26.0
Barrow's goldeneye	113.0	0.4	0.0	30.0	1.2	3.2
Bufflehead	55.0	5.2	5.8	5.5	0.8	8.4
Ruddy duck	16.0	108.0	43.0	50.5	35.0	2.8
Hooded merganser	0.0	0.0	0.0	0.0	0.0	1.2
Common merganser	10.0	1.0	26.4	0.0	1.0	0.4
Total dabblers	6,377.0	763.2	24,928.6	1,743.0	178.4	17,631.8
Total divers	334.5	312.4	248.6	248.0	105.2	102.2
Total ducks	6,711.5	1,075.6	25,177.2	1,991.0	283.6	17,734.0
Mean densities[a] per:						
acre	4.4	0.7	16.3	2.9	0.4	28.4
1,000-ft shoreline	21.5	3.4	80.6	13.4	2.1	131.1

[a] Ducks only.

study waters were used by geese during the summer. Most of the waters within grazed lands were never visited by geese.

Carp

Cornely (1980) [23] showed a close relationship between build-up of carp populations and declines of sago pondweed acreage on Malheur National Wildlife Refuge in Oregon. Waterfowl use declined dramatically in direct proportion to the reduction in sago pondweed stands. Carp control measures resulted in rapid increases in both sago pondweed acreage and waterfowl use on the refuge.

In the Columbia Basin, carp were present in many natural waters long before irrigation channels laced the area. Working in an area now innundated by Potholes Reservoir, Harris (1952) [2] noted little or no spring use by waterfowl of potholes inhabited by carp. More recent work has resulted in similar findings on wetlands of the Frenchman Hills and Winchester Wasteways complex (Foster and Tillett 1977 [14], Fletcher 1979 [3]).

During 1978 and 1979, spring and summer counts revealed three to four times as much duck use per surface acre on waters without carp as on those waters containing carp (table 2.4).

Public Use

Although long suspected, the negative impact of human activity on waterfowl use of wetlands has not

Table 2.4.—*Average daily waterfowl counts by season (1978, 1979 combined) on waters with and without carp in the Columbia Basin, Washington*

Species	With carp Spring	With carp Summer	With carp Fall	Without carp Spring	Without carp Summer	Without carp Fall
Whistling swan	10.0	0.0	10.2	21.0	0.0	11.6
Canada goose	3,510.0	13.8	1,857.4	5,477.5	123.8	893.6
Mallard	691.5	60.8	14,699.0	4,063.0	441.6	22,893.4
Gadwall	26.0	36.6	27.4	49.5	80.2	76.8
Wigeon	17.0	7.0	170.4	460.5	27.2	713.4
Pintail	64.5	7.0	552.2	2,416.5	27.8	2,538.0
Green-winged teal	57.5	2.4	164.4	69.5	7.4	674.4
Blue-winged/ cinnamon teal	0.0	33.6	1.4	14.0	174.4	48.2
Shoveler	0.0	3.4	1.4	60.0	30.4	1.4
Redhead	13.5	29.4	15.0	168.0	200.8	111.2
Ring-necked duck	1.0	0.0	0.0	12.5	8.0	9.2
Canvasback	11.0	0.0	20.2	55.5	0.6	4.6
Lesser scaup	2.0	0.0	24.6	36.0	24.2	74.8
Barrow's goldeneye	1.5	0.4	0.0	141.5	1.2	3.2
Bufflehead	13.0	1.4	4.8	47.5	4.6	9.4
Ruddy duck	2.5	6.6	1.2	64.0	136.4	44.6
Hooded merganser	0.0	0.0	1.2	0.0	0.0	0.0
Common merganser	0.0	1.2	0.0	10.0	0.8	26.8
Total dabblers	856.5	150.8	15,616.2	7,133.0	789.0	26,945.6
Total divers	44.5	39.0	67.0	535.0	376.6	283.8
Total ducks	901.0	189.8	15,683.2	7,668.0	1,165.6	27,229.4
Mean densities[a] per:						
acre	1.3	0.3	23.9	5.2	0.9	18.3
1,000-ft shoreline	6.2	1.4	118.3	24.4	3.7	87.0

[a] Ducks only.

been formally examined in the Columbia Basin. Elsewhere in this report, it has been pointed out that automobile traffic appeared to adversely influence duck use of irrigation canals. Human recreational use of Basin lakes and ponds has also been detrimental to duck and geese populations. However, waterfowl use appeared to be related to the season of public use which is itself a reflection of the type of activity.

Spring waterfowl use appeared highest on waters closed to public activity and lowest on those waters lacking restrictions (table 2.5). In between, waters open from April through July, the traditional fishing season on many Basin lakes, showed the next lowest level of duck use. Undoubtedly, duck use would have been markedly lower on fishing waters had they been open for public use during the early part of duck migration. What was observed for the April-July season reflects considerable duck use prior to fishing season which begins in mid-April.

Most recreational activities tended to wane on smaller waters during the summer. Local fishing seasons have traditionally closed on most of the Basin's trout waters in July. On other waters with seasons which extend beyond July, warmer weather and depletion of fish stocks coupled to depress enthusiasm of all but the diehards during hot summer months. Most midsummer fishing activity was concentrated on large waters such as Moses Lake, Potholes Reservoir, and Banks Lake.

Even though fishing activity and other recreation pursuits decreased on many waters during summer, the

Table 2.5.—*Average daily waterfowl counts by season (1978, 1979 combined) for wetlands by period of public use in the Columbia Basin, Washington (April through July is fishing use of wetland; October through January is mostly hunting use; year around use is both fishing and hunting. Closed category represents wetlands that are closed to public access throughout the year, or sustain extremely little public use)*

Species	April-July			October-January			Year around			Closed		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Whistling swan	13.5	0.0	11.6	0.0	0.0	10.2	6.0	0.0	0.0	11.5	0.0	0.0
Canada goose	3,331.5	1.0	2,125.6	199.5	5.6	2.8	3.5	10.2	0.2	5,453.5	120.8	622.4
Mallard	897.5	32.6	19,881.4	1,703.5	63.8	525.0	71.0	60.0	235.4	2,202.0	346.6	16,950.6
Gadwall	23.5	10.4	39.4	24.5	36.6	15.8	7.5	27.6	26.2	20.0	42.2	22.8
Wigeon	179.0	0.6	324.2	25.0	11.8	31.8	30.5	4.6	12.2	243.0	17.2	515.6
Pintail	61.0	1.6	1,660.4	363.5	6.8	175.6	40.0	3.2	82.6	2,026.5	23.2	1,171.6
Green-winged teal	16.0	0.2	163.6	25.0	2.4	24.8	37.5	1.2	8.0	49.5	6.0	642.4
Blue-winged/ cinnamon teal	0.0	20.0	2.2	10.0	42.0	36.8	4.0	26.0	2.4	0.0	119.6	8.2
Shoveler	8.5	0.0	0.0	10.0	7.0	2.8	0.0	1.6	0.0	41.5	24.6	0.0
Redhead	25.5	11.4	26.4	36.0	48.2	35.4	52.0	42.0	38.0	69.5	125.2	26.4
Ring-necked duck	6.0	3.4	8.0	0.0	0.0	0.0	0.0	0.0	1.2	7.5	4.6	0.0
Canvasback	16.5	0.4	6.6	9.5	2.6	16.0	25.0	0.0	2.2	17.0	3.0	0.0
Lesser scaup	31.0	1.0	73.0	0.0	6.8	23.0	0.0	0.0	0.4	7.0	16.4	3.0
Barrow's goldeneye	61.5	0.4	3.2	0.0	0.0	0.0	28.5	0.0	0.0	53.0	1.2	0.0
Bufflehead	48.5	1.2	9.4	1.0	0.4	4.8	0.0	0.0	0.0	11.0	3.4	0.0
Ruddy duck	11.5	18.6	3.0	0.0	47.6	40.0	11.0	27.4	1.6	44.0	49.4	1.2
Hooded merganser	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Common merganser	7.0	1.2	25.4	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.8	1.4
Total dabblers	1,185.5	65.4	22,071.2	2,161.5	170.4	812.6	190.5	124.2	366.8	4,582.5	579.4	19,311.2
Total divers	207.5	37.6	155.0	46.5	105.6	120.4	116.5	69.4	43.4	212.0	204.0	32.0
Total ducks	1,393.0	103.0	22,226.2	2,208.0	276.0	933.0	307.0	193.6	410.2	4,794.5	783.4	19,343.2
Mean densities[a] per:												
acre	3.4	0.2	54.8	4.4	0.6	2.1	0.6	0.4	0.8	6.1	1.0	24.9
1,000-ft shoreline	13.0	1.0	207.0	16.8	2.3	7.7	3.8	2.4	5.1	34.0	5.6	139.0

[a] Ducks only.

effect of intense spring recreation pressure had already taken its toll on duck use. Duck use did not rebound following cessation of spring recreation. Where public access was permitted during spring (April to July), summer use averaged 0.2 duck per acre per day (table 2.5), the lowest of any access period.

Waters where access was permitted year round supported the next lowest duck use. Improvements in this category of waters probably stemmed from a lower and less frequent rate of disturbance compared to the opening week's carnival atmosphere on seasonal trout waters. Most field biologists acknowledge that the low intensity of year-round fishing has less detrimental impacts on waterfowl use than the typical spring season. The waters with year-round public access included both hunting and fishing as well as other human recreational pursuits. Some waters were on seasonal fish management schemes which ran into September and were followed by hunting seasons in mid-October. Thus, this category should not be regarded as strictly year-round fishing.

Duck densities were highest on waters closed to, or unused by, the public. Comparatively high use was made of these protected waters during spring by ducks which carried over through summer months (table 2.5).

The effect of fall public access on spring and summer duck use was unclear. While duck use of waters in this category was higher during summer than two other public access categories, it is uncertain why ducks did not use these waters more. There were no disproportionate numbers of grazed shorelines or carp-inhabited waters in this group. In fact, carp presence and absence as well as grazed and idle wetlands were sampled in nearly equal numbers.

Fishing activity, while the most prevalent form of disturbance to waterfowl, was not the only type of human disturbance noted on intensive study waters. Again, automobile traffic on roads which followed or formed the shorelines of several lakes contributed to low use by waterfowl. This was especially evident on the Columbia National Wildlife Refuge. Other types of recreational activities ran the gamut from binocular-adorned bird watchers to unadorned skinnydippers. Individually these activities amounted to very little, but collectively, they were believed to have a significant influence on duck use of many waters.

Waterfowl Production

Breeding Population Trends

Based on breeding pair counts, duck populations in the Project have grown since first records in 1961 (fig. 2.10). A marked faltering occurred during 1973-1975, coincident with a moderately severe drought experienced in 1973. Winter and spring precipitation were well below the long-term average. Low precipitation, coupled with unusually high temperatures during May 1973, dried up many of eastern Washington's potholes before the nesting season. The effects of drought on Project wetlands, which are recharged by irrigation runoff and percolation, were believed less severe than on naturally occurring waters outside the Project area.

Although figure 2.10 shows a long-term increase in breeding ducks, it does not reveal interspecific changes in the breeding population. Historically, mallards have been the principal breeding duck, but in recent years, they have exhibited a significant decline in the Basin. Between 1970 and 1973, mallards averaged 121 pairs per year on sample waters, but only 77 pairs thereafter. Fletcher (1979) [3], working on the wetlands of Winchester-Frenchman wasteways, found that mallard broods comprised only 15.9 percent of the total duck broods produced. Broods of redhead and cinnamon/blue-winged teal were the most abundant, with an average composition of 30.0 and 20.7 percent, respectively.

Goose Nesting

Except for the Columbia River, studies of waterfowl nesting in the Columbia Basin Project lack historical antecedent. As a result, possible changes in vegetation cover use, nesting densities, or nest failures and successes, for example, cannot be related to developmental trends in irrigated farming. Therefore, information provided on waterfowl nesting in this study reflects present conditions and is, necessarily, the major basis for recommendations to managers and developers in the Basin.

Columbia Basin waterfowl nested in a wide variety of habitats. Perhaps the most predictable in their choice of nesting habitat were Canada geese. Three main factors were identified, which determined the use of an area by geese: (1) wetlands which afford protection from mammalian predators, (2) prior successful nesting, and (3) presence of brood-rearing pastures.

Protection of goose nests from mammalian predators in the Columbia Basin was offered by islands in large wetlands. Although geese have shown interest in cliff sites for nests elsewhere in Washington (Ball *et. al.* 1981) [24], few cliffs exist within the irrigated farmlands of the Project. Principal nesting areas thus occurred on large waters of the Gloyd Seeps, Moses Lake, Potholes Reservoir, and Frenchman Hills Wasteway.

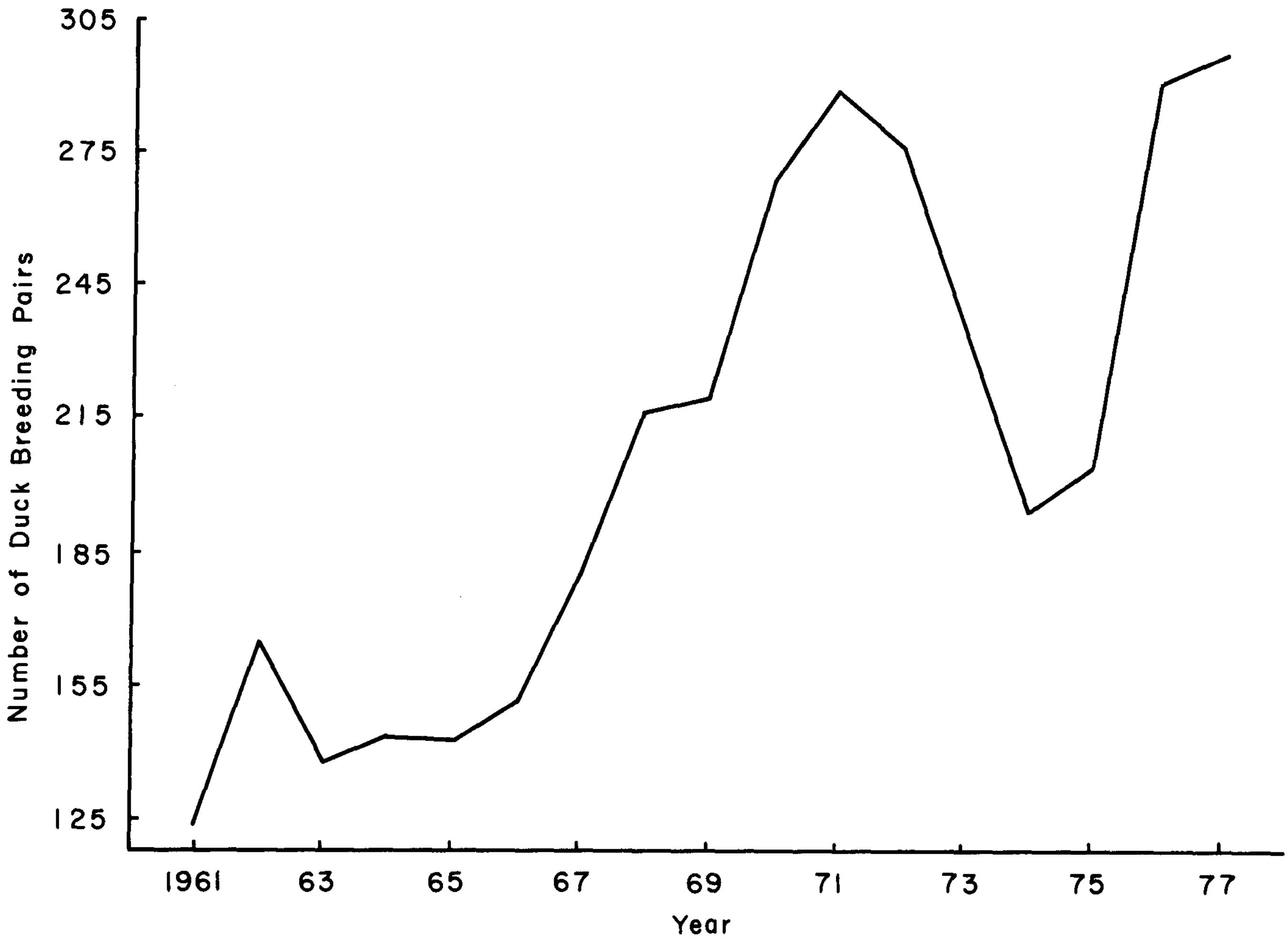

Figure 2.10.–Number of breeding pairs of ducks (all species) on selected areas in the Columbia Basin during 1961 through 1977. Lone drakes were counted as pairs. Note: Date for 1970 and 1972 are incomplete.

Nesting populations appear to be increasing within the Project. Prior to 1975, geese were not known to nest on the wasteways of the Project. Although infrequent spring counts had been made, goose broods and nests were not observed until 1975 during the course of this study. Fletcher (1979) [3] reported 20 nests and 28 broods seen on the wasteways in 1977. Similarly, Moses Lake and Potholes Reservoir have supported only a few nests and broods until recent years (Ball *et. al.* (1981) [24]. Nest searches on Moses Lake in 1981 revealed 97 goose nests.[1]

Canada geese have been present in the Project area in very low numbers since about 1910. However, breeding populations did not expand until the advent of irrigated farming. Prior to 1950, the breeding population was estimated at about 72 pairs (Yocum 1962) [25]. Irrigation delivery systems provided large water bodies, permanently isolated islands for nesting, and improved brood-rearing areas. Still, nesting increases have been slow compared with the pioneering drive of other waterfowl species. Geese are slow to assume new nesting areas, and tend to return yearly to the same area for reproduction. Using brood and nest counts, Ball *et. al.* (1981) [24] estimated a current 365 nesting pairs of Canada geese in the Columbia Basin. An additional 267 pairs nest on the Columbia River, adjacent to the Project. The estimate of 365 nesting pairs is very likely conservative, since most surveys in the Columbia Basin are based on brood counts.

Goose nest and brood counts were conducted on Moses Lake, North Potholes, Frenchman Hills, Winchester Wasteways, and Rocky Ford Creek during the present study (table 2.6). However, because of their large size and dense vegetation cover, North Potholes and Moses Lake were never thoroughly surveyed for nests or broods; therefore, data in table 2.6 probably underestimates actual nesting populations.

[1] J. Tabor, personal communication.

Table 2.6.—*Summary of observed Canada goose reproductive activity on five waters in the Columbia Basin Project, Washington, 1975-1979*

Area	Count years	No. of nests	No. of broods	No. of breeding pairs	Nesting site	Nest cover
Frenchman Hills Wasteway	76-79	20	28	—	Island	*Juncus, Carex*
Winchester Wasteway	76-79	—	3	3	Island[a]	Unknown
North Potholes	75-79	4	12	20	Island[a]	*Bromus,* forbs
Moses Lake	75-77	9	21	—	Island[a]	*Juncus, Carex*
Rocky Ford Creek	76-79	—	9	—	Unknown	Unknown

[a] Island nesting suspected. Young broods were observed near islands.

All observed nests of Canada geese were situated on islands, generally over 100 feet from mainland, and separated by water greater than 3 feet deep. Nest sites were located in both upland vegetation types, such as bunchgrasses, cheatgrass, and various forbs, and in wet soil vegetation (sedges and rushes), which commonly occupied parts or all of the many islands surveyed.

Nesting of geese on Rocky Ford Creek is uncertain because nests were never found. The stream is small (average <20 feet wide), and generally not descriptive of goose nesting habitat. However, the streambanks offer excellent brood pasture since cattle and sheep have grazed the coulee bottom for many years. More likely, young originate from nests on Moses Lake, then move into Rocky Ford Creek for rearing.

Duck Nest Location, Densities, Success

Nesting studies on ducks were conducted in various habitats between 1976 and 1979. Table 2.7 summarizes the results of searches on nearly 3,200 acres of land during four years. Wetland, as used in table 2.7, encompassed land within 300 feet of a study water. Areas greater than 300 feet distant were grouped with other untilled lands and classed as "uplands." None of the wetland areas searched contained agricultural crops: vegetation was either marsh plants or natural upland shrubs, forbs, and grasses.

Ducks nested on roadside strips less than any other class of surveyed lands. By contrast, nesting was 17 times higher on wetlands, the highest of any land class (table 2.7). Ducks showed no significant differences in nesting between ditchbanks and agricultural croplands.

The principal crops of the Columbia Basin Project in terms of planted acres are alfalfa, wheat, corn, potatoes, beans, and barley, in that order. With the exceptions of potatoes and beans, each of these crops were sampled for use by nesting ducks. Mint was also included, although this crop comprises only a very small amount of Projet farm production.

Blue-winged teal and mallard were the most commonly identified nesters in croplands. Specific identification of some hatched nests were differentiated only as "dabbler" or "diver" nest. Other nests, which had been pilfered by predators (especially mammals), were often impossible to identify under field conditions.

Of the croplands searched, alfalfa was almost exclusively the only crop utilized, with about one duck nest found for each 43 acres searched. Although pheasants tended to nest in irrigated wheat quite readily, only one duck nest was discovered in 116 acres of this crop. For mint, seven fields totaling 42 acres yielded only one duck nest. Barley and corn were not used by nesting ducks insofar as this study could determine. Sample sizes (number of fields) and location were probably inadequate to ascertain extent of nesting in barley, corn, and mint crops.

Although over three dozen major crops are grown in the Columbia Basin Project, very few of these offer suitable nesting cover, especially during initial nesting attempts. Crops such as potatoes, corn, beans, onions, carrots, and asparagus develop almost no foliar cover until midsummer. At this date, only renesting attempts by late-nesting teal are likely to occur in these crops.

For dabbler nests located on upland and wetland classes, the number of nests was inversely related to

Table 2.7.—*Summary of nest searches for ducks on various classes of lands in the Columbia Basin, Washington, 1976-1979*

Species	Roadsides[a]	Number of nests by land type: Canal/ditch banks[a]	Crops[a]	Untilled uplands	Wetlands	Total
Mallard	1	6	15	13	17	52
Gadwall	1	0	2	6	9	18
Blue-winged/cinnamon teal	1	3	5	11	52	72
Unidentified dabbler	4	0	3	5	31	43
Redhead	0	0	0	0	24	24
Lesser scaup	0	0	0	0	3	3
Ruddy duck	0	0	0	0	14	14
Total nests	7	9	25	35	150	226
Acres searched	475	445	1,210	432	606	3,168
Acres per nest	67.9	49.4	48.4	12.3	4.0	14.0

[a] Searches conducted during 3 years only, 1976-1978.

distance from open water (fig. 2.11). Unfortunately, precise measurements were made on only 85 (59 percent) of the dabbler nests found in these two land classes. However, the relationship shown in figure 2.11 appears strong enough to be reliable. About 68 percent of all measured dabbler nests were located within 100 feet of water. The average distance was 92 plus or minus 10 feet ($\bar{X} \pm$ SE). Most studies of dabbling ducks have shown that nests are located within 100 yards of water (Bellrose 1976) [6], but distances as great as one mile have been recorded (Duebbert and Lokemoen 1976) [26]. In the present study, one gadwall nest was located in dense sagebrush and grass, approximately 0.75 mile from open water. The greatest distance recorded for mallard nests was 0.3 mile; and for teal, 630 feet.

Although vegetation cover on many upland areas was severely limited, no dabbler nests were found in marsh growth over water in this study as has been reported by Wingfield (1951) [27] and Krapu *et al.* (1979) [28].

Redhead, lesser scaup, and ruddy duck were the only diving ducks for which nests were found. Only three lesser scaup nests were discovered; two within 25 feet, and one at 165 feet from water. Nests were located in tall, dense cheatgrass and big sagebrush. With one exception, redheads and ruddys nested exclusively over water in emergent stands of cattail or hardstem bulrush. The mean distance of 19 nests from open water was 17 plus or minus 4 feet for these two species. Both redhead and ruddy ducks have been reported to nest away from water (Lokemoen and Duebbert 1973 [29], McKnight 1974 [30]). McKnight (1974) found 72 percent of 69 redhead nests and 14 of 15 ruddy nests on dry ground at Fish Springs National Wildlife Refuge, Utah. These findings indicate that the classically held belief that redhead and ruddy ducks are dependent solely upon emergent vegetation should be reconsidered.

Harris (1952) [2] and Johnsgard (1955) [31] provided information on vegetation cover for 110 upland duck nests in the vicinity of Potholes Reservoir between 1950 and 1954. According to their combined data, 48 percent of the nests were sheltered by rabbitbrush and baltic rush. They found very low use of sagebrush for nesting cover (table 2.8). In general, nesting cover preferences did not differ greatly between the three studies for major cover groups. Baltic rush and three-square bulbrush with similar densities, growth form, and phenologies were frequently codominants along the edge of ponds. Because of this, ducks probably showed no appreciable distinction between the two species as was suggested by the data for the 1950-1954 period.

Table 2.8 shows a considerable decline in the use of rabbitbrush, and an increase in nesting under sagebrush. We suspect, based on observations elsewhere in the Project, that sage has increased in both crown cover and density since the early 1950's on undisturbed areas, thus becoming more available and attractive to upland nesters.

The fact that 20 to 30 percent of duck nesting occurred in wet soil vegetation supports the belief that the majority of ducks in the Columbia Basin nest very near water (fig. 2.11). A relatively narrow strip

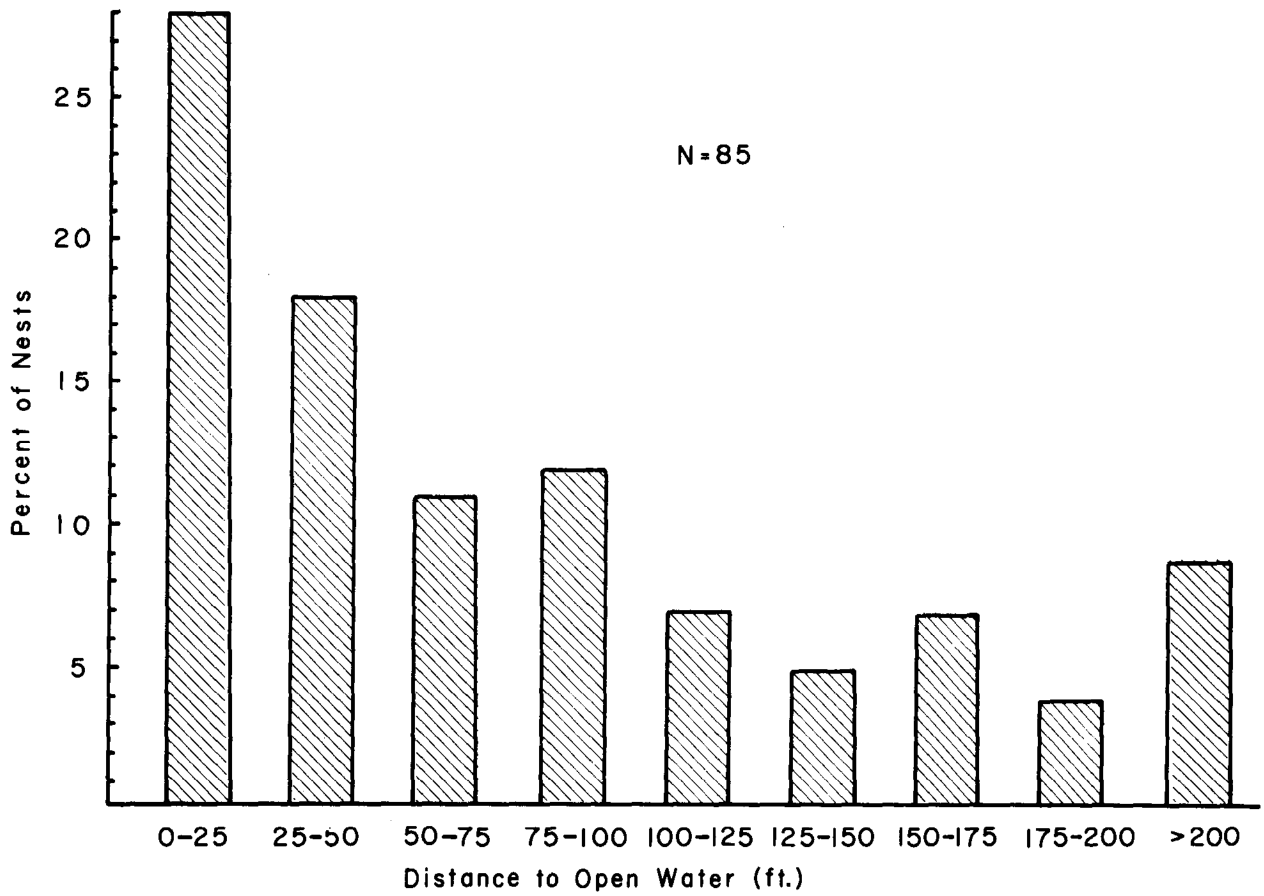

Figure 2.11.–Percent of dabbling duck nests found at various distances from open water in the Columbia Basin, 1977-1979.

of vegetation surrounding individual wetlands appears to account for the bulk of duck production throughout the Project. Of the nests for which measurements were made, only six were more than 100 yards from water.

Because of conflicts in field work, intensive nest searches were not started until late May or early June. Because of this, most of the early mallard nesting was missed. Hence, the active mallard nests in table 2.9 probably contain some renesting attempts. Since most nests rapidly deteriorate once a site is abandoned, many early and perhaps successful nests escaped detection by field crews. We believe there were more attempts by mallards than the data show. Gadwall and teal normally nest later than mallards. For these ducks, nest searches occurred during the peak of nesting activity.

Fewer acres of classic diver nesting habitat were searched than were covered for dabblers. Only about 100 acres of emergent vegetation were sampled of the total listed under "wetlands" in table 2.7. Thus, tables 2.7 and 2.9 are not meant to point out relative differences in abundance between dabbling and diving ducks.

Follow-up checks on active duck nests to determine their fate were not done, so nesting success (i.e., at least one egg hatched in a nest) was not determined. Of 225 duck nests found between 1976 and 1978, data on nest status was collected for 169 nests (table 2.9). At least 54 percent (92 nests) of the nests found did not hatch. Since the fate of 25 active nests shown in table 2.9 was undetermined, total nesting success was unknown; but at least 31 percent of the total nests hatched.

The rate of known desertion was low (5 percent) for all species. Other research has shown that desertion in mallards averages 10 to 15 percent, about 20 percent for bluewings, and as high as 37 percent for readheads, prompting Bellrose (1976:323) [6] to state that "*The redhead appears to be its own worst enemy.*" Desertion may have been higher in the Basin than was observed, but this presupposes that duck hens voluntarily abandoned nests. Biologists suspect that most desertion results from harrassment by predators, although proof of this is almost impossible to attain.

Disruption of duck nests by predators amounted to at least 30 percent. Four additional nests were

Table 2.8.—*Upland and wet soil vegetational cover used for nesting by dabbling ducks in earlier studies compared to the present study in the Columbia Basin Project, Washington*

	Number of Nests		
	1950-1954[a]	1977-1979	Total
Juncus balticus	24	16	40
Chrysothamnus spp.	29	10	39
Artemisia tridentata	3	17	20
Scirpus americanus	0	14	14
Elymus cinereous	13	0	13
Bromus tectorum	8	1	9
Psoralea lanceolata	8	0	8
Grayia spinosa	7	0	7
Distichlis stricta	4	2	6
Salsola kali	2	4	6
Rosa woodsii	6	0	6
Agropyron spicatum	0	5	5
A. cristatum	0	4	4
Vicia sp.	0	4	4
Residual forbs	0	3	3
Salix sp.	1	2	3
Carex sp.	0	2	2
Poa bulbosa	0	2	2
Amaranthus sp.	2	0	2
Oryzopsis hymenoides	2	0	2
Hordeum jubatum	0	1	1
Sarcobatus vermiculatus	0	1	1
Chenopodium album	0	1	1
Apocynum cannabinum	0	1	1
Latuca scariola	1	0	1
Totals	110	90	200

[a] Data from both authors combined: Harris (1952 [2]); Johnsgard (1955 [31]).

destroyed by predators, but we could not determine whether birds or mammals were involved. These are included under "unknown" in table 2.9. Destruction by man's activities accounted for 16 (11 percent) nest losses, mostly in the mowing of alfalfa. One nest was destroyed by fire, and one by tractor and disk in a stubble field. Only three hens on active nests in alfalfa were killed by mowers.

Of 92 unsuccessful nests, 50 (57 percent) were destroyed by predators (table 2.9). Birds were by far the most prevalent predator. The most likely avian culprits were ravens, magpies, and ring-billed gulls. Avian predators have been identified as the primary cause of duck egg losses by several researchers (Wingfield 1951 [27]; Nelson and Klett 1952 [32]; Odin 1957 [33]). Gulls were abundant during all years of study; at least three nesting colonies occurred in the study area. Pheasant nests and recently hatched chicks exposed during alfalfa mowing were readily preyed upon by gulls in this study, but very low predation was noted on nests placed in tall, dense cover for both pheasants and ducks.

Nest parasitism was observed twice. In both, pheasant eggs were deposited in duck nests, leading to desertion of one nest. Five duck eggs were hatched from the second nest, but the four pheasant eggs were abandoned.

Conventional views on the relationship of waterfowl reproductive success and grazing have met serious challenges in recent years (Keith 1961 [34], Mihelsons 1968 [35], Kirsch 1969 [19], Gjersing 1975 [36], Mundinger 1976 [37]. In Washington, this relationship has never been formally addressed, even though the livestock industry is large. Both private and public lands in the Columbia Basin Project have had a long history of grazing.

The effects of grazing on waterfowl nesting were determined during this study on from 12 to 21 sites

Table 2.9.—*Status of 169 duck nests in the Columbia Basin, Washington, 1976-1979*

Species	No. of nests	Nest Status						
		Active	Hatched	Deserted	Destroyed			
					Mammal	Bird	Man	Unknown[a]
Mallard	25	6	6	2	0	0	10	1
Gadwall	12	4	3	1	1	2	1	0
Blue-winged/cinnamon teal	62	7	15	4	4	25	3	4
Unknown dabbler	41	5	12	2	4	6	4	8
Redhead	17	1	11	0	0	4	0	1
Lesser scaup	2	0	1	0	0	0	0	1
Ruddy duck	10	2	4	0	0	0	0	4
Total dabblers	140	22	36	9	9	33	18	13
Total divers	29	3	16	0	0	4	0	6
Total ducks	169	25	52	9	9	37	18	19
Percent of total	100	15	31	5	5	22	11	11

[a] Includes four nests destroyed by predators, but whether bird or mammal was undertermined.

between 1977 and 1979. Individual sites varied from 0.5 to 84.5 acres, averaging 20.1 acres. Nesting attempts (table 2.10) in ungrazed wetlands and adjoining uplands were nearly twice as high as on similar grazed areas ($\chi^2 = 3.8$, $P < 0.05$). As suggested earlier (cf. table 2.7 and related discussion), the differences in nesting attempts increased with nearness to water. Within approximately 100 feet of water, nesting densities were four to five times greater on ungrazed land than on grazed areas.

Diving ducks showed no statistical differences in nesting attempts between grazed and ungrazed wetlands. However, obvious effects were seen on severely grazed or trampled marshes: a few areas supported no standing emergents. These areas were devoid of redhead and ruddy duck nests.

Dabbling ducks showed the strongest preference for ungrazed areas ($\chi^2 = 10.7$, $P < 0.01$). Where dabblers nested on grazed lands, nest locations could usually be predicted before making a thorough search. Clumps of large, spreading shrubs (sagebrush, rabbitbrush, greasewood), remnant stands of rushes, or a dense patch of residual forbs were the only places used as nest sites. By and large, these niches were in scarce supply where grazing had occurred for any lengthy period.

The amount of nest failures was not significantly different between grazed and ungrazed lands.

The effect of grazing intensity, season of use, and grazing history on duck nesting were not determined for several reasons. Grazing records of several areas were not kept, or at least could not be located. Furthermore, records and recollections were not always reliable since trespass (unauthorized) grazing has been a problem on public lands for many years. And because of inadequate staffing, management agencies have not been able to closely regulate either grazing intensity AUM's (animal unit months) or season of use. Based on subjective information, we attempted to analyze intensity and season of use, but too few samples of one or more treatments led to unreliable results.

Brood Densities

During a cooperative study of the Winchester and Frenchman Hills Wasteways and adjacent wetlands in 1976 and 1977, an estimated minimum of 1,200 duck broods were produced on these flatland waters each year (Fletcher 1979) [3]. With an average brood size of 5.2 for all species of age classes IIb–III (Gollop and Marshall 1954) [5] about 6,250 ducklings were fledged yearly on 4,308 usable acres of lakes, ponds, and marshes of the wasteway sytem (0.28 brood per acre). Unusable wetlands were defined as those with less than 5 percent open water and lacking standing water during most of the breeding season (Fletcher 1979) [3].

Table 2.10.—*Comparison of duck nest attempts and densities on grazed and ungrazed lands in the Columbia Basin, Washington, 1977-1979*

	1977	1978[a]	1979	Total
Grazed				
Dabblers	9	0	6	15
Divers	8	0	0	8
Acres searched	143	58	117	318
Acres/nest	8.4	—	19.5	13.8
Ungrazed				
Dabblers	31	21	22	74
Divers	3	12	6	21
Acres searched	164	294	271	729
Acres/nest	4.8	8.9	9.7	7.7

[a] Disproportionate sampling of grazed and ungrazed lands in 1978 resulted from cessation of grazing on several established study sites.

During 1978 and 1979, studies on 74 waters provided estimates of 0.07 and 0.17 duck brood per acre, respectively (table 2.11). Considering only the flatland class of waters, brood densities were 0.08 and 0.21 brood per acre in 1978 and 1979, respectively. Whereas data for 1979 indicate a return to the brood densities observed earlier, the low of 1978 corresponds with the low number of observed breeding pairs (fig. 2.12).

Factors Affecting Production

Wetland Basin Type

The bulk of duck production in the Project occurred on wetlands under State management. Twice as many broods were observed per surface acre of State wetlands as on Federal or private wetlands. Although a number of factors probably contributed to their differences in production, general wetland morphometry was believed to have played the biggest role. Most State wetlands were similar in basin structure to the "flatland" class described earlier. Densities of 0.14 and 0.09 duck brood per acre were observed on flatland and scabrock basins, respectively (table 2.12). The difference was significant ($\chi^2 = 11.42$, $P < 0.01$). Separate chi-square analyses indicated both driver and dabbler broods were significantly higher ($P < 0.05$) on flatland waters than on the scabrock type.

Surface Area

Field work in 1976 and 1977 indicate that broods of both diving and dabbling ducks were observed more frequently on wetlands smaller than 20 acres (Fletcher 1979) [3]. Studies in 1978 and 1979 examined this relationship in greater detail. Highest densities of ducklings were observed on wetlands five acres or less in size, and were particularly abundant on wetlands from 0.1 to 1.0 acre (cf. fig. 2.8). Considering that the majority of the ducks observed during summer were ducklings, figures 2.8 and 2.9 portray fairly closely the inverse relationship between numbers of duck broods and size of wetland.

Water Depth

Observations on 505 flatland waters in 1976 and 1977 revealed that duck broods were significantly more abundant on wetlands greater than 3 feet deep ($\chi^2 = 102.71$, $P < 0.005$). Sixty-five percent of 1,380 duck broods were seen on 39 percent of the wetlands. These wetlands made up 51 percent of the total surface area available to broods. On waters less than 3 feet deep, brood densities (all species) were 0.23 per acre. Deeper waters supported densities of 0.41 brood per acre. Both diver and dabbler broods shared equally in all the foregoing comparisons.

Open Water

The amount of open water in a wetland appeared to have a strong influence on brood distribution. However, estimating this influence can be difficult. As pointed out by Diem and Lu (1960) [38] and Hammond (1970) [4], the more open a wetland is, the more likely a brood is to be observed. During studies on the flatland waters in 1976 and 1977, Fletcher

Table 2.11.—*Total estimated duck production*[a] *on 74 study waters in the Columbia Basin, Washington, 1978-1979*

Species	1978 No. broods	1978 No. young	1979 No. broods	1979 No. young	2-year mean No. broods	2-year mean No. young
Mallard	54	335	99	614	76.5	474
Gadwall	6	35	68	394	37.0	214
Wigeon	0	0	15	60	7.5	30
Pintail	0	0	3	21	1.5	11
Blue-winged/cinnamon teal	3	16	60	318	31.5	167
Shoveler	3	14	19	91	11.0	52
Redhead	37	189	75	382	56.0	286
Canvasback	3	15	3	15	3.0	15
Lesser scaup	0	0	3	12	1.5	6
Ruddy duck	35	189	39	211	37.0	200
Total dabblers	66	400	264	1,498	165.0	948
Total divers	75	393	120	620	97.5	507
Total	141	793	384	2,118	264.0	1,455
Mean density per:						
acre	0.07	0.37	0.17	0.95	0.12	0.67
1,000-ft shoreline	0.32	1.79	0.84	4.61	0.58	3.24

[a] Observed number of broods adjusted by species visibility factor as determined by Fletcher (1979 [3]). Number young calculated from average brood sizes observed in 1978 and 1979.

(1979:38) [3] tested ways of lowering this bias. By testing the sightings of dabbler and diver broods against deep and shallow water marshes, he found significant differences between the amount of open water and brood distribution. Neither dabblers nor divers were seen as frequently as expected on closed habitats (i.e., less than 25 percent open water). Dabblers were seen more often on both deep and shallow marshes where open water amounted to 26 to 75 percent of the surface area. Divers, on the other hand, were observed more frequently on the most open (76 to 100 percent) wetlands on both deep and shallow waters. The same general relationship was again observed in 1978 and 1979 on a smaller sample of waters. For dabbler broods, densities were 0.17, 0.20, and 0.08 brood per acre on open, moderately open, and nearly closed wetlands, respectively.

Submergent Vegetation

Too much emergent vegetation restricts duck brood distribution, yet it is desirable in moderate amounts. Emergent plants are needed for cover, but they are also important to young ducks as a source of aquatic insects which use emergents as a substrate (Collias and Collias 1963) [39]. However, older ducklings tend to favor submergent vegetative foods and hence would be expected to be seen more frequently on wetlands with submergent plants than on those without. This was evident during 1976-1979 studies. Pooled observations (i.e., combined young and older ducklings) showed dabbler and diver broods were significantly more abundant where submergent vegetation was present than on wetlands lacking these plants ($\chi^2 = 164.01$, $P < 0.005$).

Carp

The presence of carp in a wetland is generally known to be detrimental to waterfowl use and brood distribution (Johnson 1964) [40]. Harris (1952) [2] associated relatively low-brood densities in the Potholes area of Grant County with presence of carp.

Research on the influence of carp on duck broods is complicated by several problems. Many of the variables known to affect brood numbers are intertwined and not easily separable for analytic purposes, e.g., wetland size, livestock grazing, human

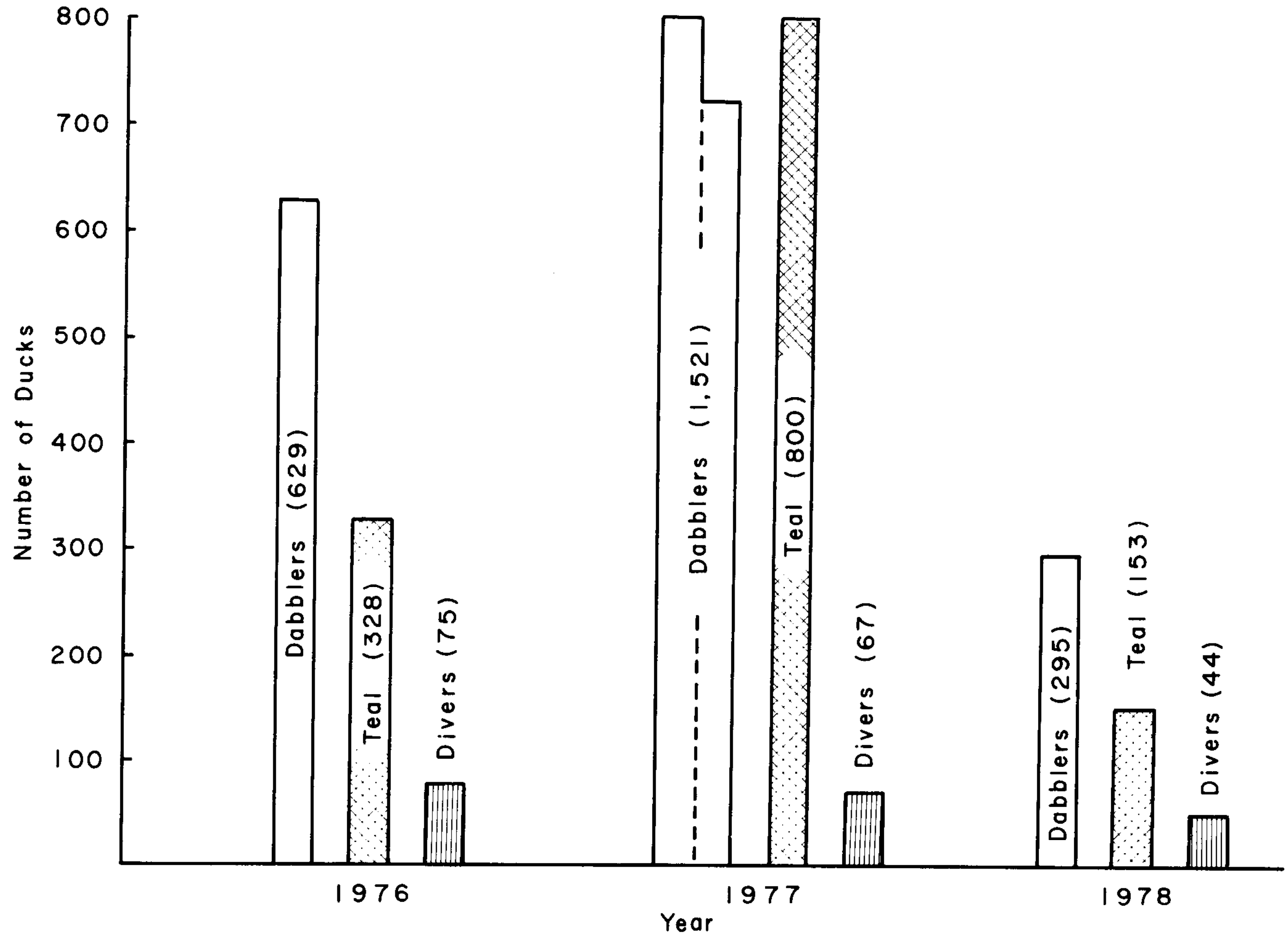

Figure 2.12.–Numbers of breeding pairs and single drake ducks on Frenchman Hills and Winchester Wasteways between 20 May and 2 June, 1976-1978, Columbia Basin, Washington. Data for dabblers include teal count.

disturbance, amount of open water, and presence or absence of submergent vegetation. Further complicating the assessment is the abundance of carp in a given wetland. Where carp numbers are low, wetlands may be capable of supporting relatively good numbers of duck broods. High densities of carp, however, are known to severely reduce or eliminate submergent vegetation, a prime waterfowl attractor in most wetlands (Anderson 1950 [41], Weir and Starr 1950 [42], Tyron 1954 [43], Robel 1961 [44], King and Hunt 1967 [45]). Carp control efforts on Malheur Refuge in Oregon resulted in a resurgence of sago pondweed, the most valuable waterfowl food in Malheur Lake, and a correspondingly dramatic increase in waterfowl use-days (Cornely 1980) [23].

In the Columbia Basin, carp influences were studied on all waters of the Frenchman Hills and Winchester Wasteways systems in 1976 and 1977. During 1978 and 1979, studies included only a sample of these wetlands plus the sample of scabrock lakes.

In comparing isolated ponds (i.e., those not connected to wasteways), both dabbler and diver broods were seen less than expected on wetlands containing carp, although chi-square analysis showed the difference was significant only for divers (Fletcher 1979) [3]. No estimates were obtained on carp abundance for isolated wetlands; therefore, this factor did not enter the analysis. As mentioned earlier, a strong attraction of wetlands is the presence of submergent plants for food. Cursory field observations indicated that while some ponds had carp, numbers were low enough to have little impact on submerged plants. Therefore, a simple test of carp presence or absence may often be inconclusive in the absence of data on carp abundance for each wetland.

By comparing areas of known carp densities, both divers and dabblers were found to be more abundant where carp occurred in relatively low densities ($\chi^2 = 43.4$ and 39.5, respectively, $P < 0.005$). Duck brood densities were three times higher per acre

Table 2.12.—*Estimated yearly production of ducks on 74 scabrock and flatland waters of the Columbia Basin, Washington, 1978-1979 (data represents 2-year means)*

Species	Scabrock		Flatland	
	No. broods	No. young	No. broods	No. young
Mallard	30	186	46.5	288
Gadwall	9	52	28	162
Wigeon	3	12	4.5	18
Pintail	1.5	11	0	0
Blue-winged/cinnamon teal	17	90	14.5	77
Shoveler	1.5	7	9.5	46
Redhead	15.5	79	40.5	206
Canvasback	0	0	3	15
Lesser scaup	1.5	6	0	0
Ruddy duck	15	81	22	119
Total dabblers	62	358	103	591
Total divers	32	166	65.5	340
Totals per year	94	524	168.5	931
Mean densities per:				
acre	0.09	0.52	0.14	0.80
1,000-ft shoreline	0.21	1.17	0.82	4.45

(0.24 vs. 0.08 brood) than in wetlands heavily infested with carp.

The data for 1978-1979 appear to show less distinction in brood numbers in relation to the presence or absence of carp (table 2.13). The apparently weaker response to carp absence was masked by other variables which were unaccounted for in table 2.13. First, 1978 was a year marked by extremely low breeding pairs of ducks and correspondingly low production. This low production biased results in that only a comparatively few wetlands had any broods at all. A second factor was the inclusion of scabrock lakes, many of which lack carp, but contain game fish which sparked the interest of fishermen. Human disturbance was undoubtedly a major inhibitor to duck brood distribution and use.

Livestock Grazing

Cattle grazing appeared to depress distribution and abundance of duck broods during all 4 years of study. Fletcher (1979) [3] calculated 0.44 brood per acre on ungrazed areas and 0.19 for grazed wetlands between 1976 and 1977. With generally lower breeding populations in 1978 and 1979, brood densities of 0.14 and 0.08 were found on idle and grazed wetlands, respectively (table 2.14). The pooled data for 1976-1979 showed highly significant differences of brood sightings between ungrazed and grazed areas. Both dabbler and diver broods were seen more often where no grazing occurred ($\chi^2 = 148.6$ and 43.4, respectively, and $P < 0.005$).

Seasonal grazing patterns, inasmuch as known, were also tested to find possible differences in associated brood numbers. Duck broods in general were more numerous where grazing seasons ran from November through April. However, this generality was heavily weighted to diver broods (table 2.15). Both dabbler and diver broods were only infrequently encountered on wetlands grazed in late spring and summer. Dabbler broods appeared most often on grazed lands where grazing extended throughout the year.

Public Use

Brood numbers on all wetlands were conspicuously affected by human disturbance. Disturbance was largely a result of recreational activity on and about the wetlands. Quantitative measures of recreational activity were impractical to attain for the study waters, thus precluding comparisons between user-days (intensity of use) and numbers or distribution of

Table 2.13.—*Estimated yearly production of ducks on 72 waters[a] with and without carp in the Columbia Basin, Washington, 1978-1979 (data represent 2-year means)*

Species	Carp present		Carp absent	
	No. broods	No. young	No. broods	No. young
Mallard	12	74	64.5	400
Gadwall	10	58	26	151
Wigeon	1.5	6	6	24
Pintail	0	0	1.5	10
Blue-winged/cinnamon teal	2.5	13	29	154
Shoveler	0	0	11	53
Redhead	9	46	47	240
Canvasback	0	0	3	15
Lesser scaup	0	0	1.5	6
Ruddy duck	3	16	34	184
Total dabblers	26	151	138	792
Total divers	12	62	85.5	445
Total ducks	38	213	223.5	1,237
Mean densities per:				
acre	0.08	0.44	0.13	0.74
1,000-ft shoreline	0.29	1.61	0.71	3.94

[a] Two wetlands deleted for lack of confirmation on carp status.

duck broods. The next best method categorized wetlands according to season of greatest recreational activity. Some wetlands sustained virtually no human use because access was prohibited.

Young ducks, in general, were most frequently encountered on waters which were closed all year or were used only during winter months. Brood densities on these waters were comparable (table 2.16). Where recreation use occurred year round or was concentrated during spring and early summer, brood numbers were at lowest levels (table 2.16).

Some differences were observed between sightings of diver broods in the various seasons and those for dabblers. Diver broods were seen most freqeuntly on waters where human use occurred only during the fall season (table 2.17). Surprisingly, wetlands which had no recreational activity supported fewer diver broods or were not significantly different from wetlands under different use patterns. Dabblers responded most favorably to wetlands which were never used by recreationists (table 2.17).

Wetland Drainage

Loss of wetlands has been the principal cause of waterfowl declines over much of North America. Whether or not losses have occurred in the Columbia Basin remains a moot point. We observed, during this study, filling of wetlands for crops. We also observed improper management of some public waters which rendered them useless to waterfowl. But new wetlands have formed and some older ones increased in size.

Wetland gains and losses have been rapid and extensive in the Columbia Basin since the beginning of irrigation in the early 1950's. Irrigation brought surface storage impoundments and also elevated groundwater tables (fig. 2.13). A complete inventory of Columbia Basin wetlands has not been attempted in recent years. An early inventory, completed in 1954, documented 6,164 acres of permanent standing water in Grant County, the largest and wettest of the three-county Project area (U.S. Fish and Wildlife Service 1954) [46]. An update of this inventory in 1975-1976 showed standing water wetlands had increased to 14,019 acres, an increase of 127 percent (Ball *et al.* 1977) [47]. Impoundments, streams, irrigation canals and drains were not included in either of these totals. The above wetlands occurred on nonirrigable lands or in areas where drainage was not physically or economically feasible. The Project has had a long history of wetlands developing on irrigable land where the water table eventually reaches

Table 2.14.—*Estimated yearly production of ducks on grazed and ungrazed wetlands*[a] *in the Columbia Basin, Washington, 1978-1979 (data represent 2-year means)*

Species	Grazed		Idle	
	No. broods	No. young	No. broods	No. young
Mallard	14	87	62.5	388
Gadwall	8	46	29	168
Wigeon	1.5	6	6	24
Pintail	0	0	1.5	10
Blue-winged/cinnamon teal	9	48	22.5	119
Shoveler	0	0	11	53
Redhead	6	31	50	255
Canvasback	3	15	0	0
Lesser scaup	0	0	1.5	6
Ruddy duck	11	59	26	140
Total dabbler	32.5	187	132.5	762
Total divers	20	105	77.5	401
Total ducks	52.5	292	210	1,163
Mean densities per:				
acre	0.08	0.47	0.14	0.75
1,000-ft shoreline	0.38	2.13	0.67	3.73

[a] Sample size was 74 waters.

Table 2.15.—*Estimated yearly production of ducks on 36 grazed wetlands in relation to season of grazing in the Columbia Basin, Washington, 1978-1979 (data represent 2-year means)*

Species	November-April		May-July		Year around	
	No. broods	No. young	No. broods	No. young	No. broods	No. young
Dabblers	5.8	34	2.0	11	24.7	142
Divers	16.2	85	1.6	8	2.2	12
Total	22.0	119	3.6	19	26.9	154
Mean densities per:						
acre	0.16	0.87	0.02	0.11	0.10	0.60
1,000-ft shoreline	0.56	3.02	0.10	0.54	0.42	2.42

the surface. Most of these wet areas never held standing water for any length of time nor developed beyond the point of supporting wet-soil vegetation. However, for at least a portion of the year, high soil moisture prevented their tillage. Figure 2.14 depicts the trend in wetland formation on irrigable lands of the Basin.

Because of topography, soil characteristics and water application rates, some of these wet soil areas on irrigable lands were destined to become permanent wetlands of standing water of value to waterfowl. Other, less fully developed wetlands offered little or no value to waterfowl, but because of the associated vegetation would become a critical

Table 2.16.—*Estimated yearly production of ducks for 74 waters under four seasons of recreational use in the Columbia Basin, Washington, 1978-1979 (data represent 2-year means)*

Species	April-July		October-January		Year around		Closed all year	
	No. broods	No. young	No. broods	No. young	No. broods	No. young	No. broods	No. young
Mallard	9	56	12	74	12	74	43.5	270
Gadwall	3	17	14	81	7	41	13	75
Wigeon	3	12	0	0	0	0	4.5	18
Pintail	1.5	10	0	0	0	0	0	0
Blue-winged/cinnamon teal	8	42	5	26	5.5	29	13	69
Shoveler	0	0	1.5	7	0	0	9.5	46
Redhead	5.5	28	28.5	145	9.5	48	12.5	64
Canvasback	0	0	1.5	8	0	0	1.5	8
Lesser scaup	1.5	6	0	0	0	0	0	0
Ruddy duck	6	32	13	70	11	59	7	38
Total dabblers	24.5	137	32.5	188	24.5	144	83.5	478
Total divers	13	66	43	223	20.5	107	21	110
Total ducks	37.5	203	75.5	411	55	251	104.5	588
Mean densities per:								
acre	0.09	0.51	0.15	0.84	0.10	0.47	0.13	0.75
1,000-ft shoreline	0.35	1.89	0.63	3.44	0.68	3.12	0.74	4.16

aspect of pheasant and nongame habitat in otherwise intensively farmed areas. Drainage programs were implemented to reduce the amount of potentially irrigable land from "going wet." Thus, figure 2.14 shows only the total wetland acreage at any given time, and does not approach the acreage of wetlands which would have developed in the absence of drainage. Wet areas began forming almost as soon as water was applied to the land back in 1951 and was paralleled by construction of open drains to deal with the problem. Later, more efficient subsurface drains were used to reduce wetland formation (fig. 2.15). The Bureau of Reclamation (1976) [48] has predicted that virtually no wetlands on irrigable lands will remain in the Project after about 1990.

Fall and Winter Seasons

Migrations, Populations, and Harvest Trends

Near the end of August as the reproductive season draws to a close, waterfowl numbers begin to swell throughout the Basin (figs. 2.3, 2.7). In early September, waterfowl counts climb sharply from a combination of early migrating birds and, presumably, ingress from wetlands outside the Project. This early fall buildup far exceeds what can be attributed to local production, and opinions are divided on the extent of the early migrant contribution (particularly mallard ducks). Some hold that the large number of mallards in the August and September populations come from production within the Project, plus a sizeable boost from production on other wetlands throughout central Washington. The alternative view is that local production is supplemented heavily by early migrant mallards arriving in the Basin with pintail and green-winged teal from Canadian breeding areas. Post-hatch-banding studies in central Washington have not resolved the issue.

The main fall migration usually arrives in central Washington in late November. Mallards make up the bulk of these later migrants, having been preceded by pintails, gadwalls, teals, and the diving ducks. Mallards linger in the north as long as waters remain ice free. Thus, the arrival time of most migrant mallards in the Columbia Basin depends on weather patterns. In some years, peak numbers occur in October (1977, fig. 2.16); but, the peak may not develop until as late as December (1976, fig. 2.16) in other years. Since most mallards come from Alberta and British Columbia, weather conditions in the Columbia Basin frequently cannot be used to predict when birds will arrive in the Basin.

Table 2.17.—*Results of chi-square tests showing relationship of diver and dabbler duck brood numbers to season of human recreation use of wetlands in the Columbia Basin, Washington, 1978-1979*

Season of recreation	Wetland acres	Number of broods: Divers, Observed	Divers, Expected[a]	Dabblers, Observed	Dabblers, Expected
April–July	397	13.0	25.2	24.5	26.7
October–Janaury	489	43.0	30.8	32.5	30.8
		χ^2 = 10.74, P<0.01		χ^2 = 0.28, NS[b]	
April–July	397	13.0	14.4	24.5	21.1
Year around	531	20.5	19.1	24.5	27.9
		χ^2 = 0.24, NS		χ^2 = 0.96, NS	
April–July	397	13.0	11.6	24.5	36.0
Closed all year	781	21.0	22.4	83.5	71.3
		χ^2 = 0.26, NS		χ^2 = 5.76, P<0.05	
October–January	489	43.0	30.5	32.5	32.2
Year around	1,020	20.5	33.0	24.5	34.8
		χ^2 = 9.86, P<0.01		χ^2 = 3.05, NS	
October–January	489	43.0	25.0	32.5	45.2
Closed all year	781	21.0	39.0	83.5	70.8
		χ^2 = 21.3, P<0.01		χ^2 = 5.85, P<0.05	
Year around	531	20.5	16.6	24.5	43.2
Closed all year	781	21.0	24.9	83.5	64.8
		χ^2 = 1.53, NS		χ^2 = 13.49, P<0.01	

[a] Number of broods expected to be seen if no selection relative to season of human recreational use exists, i.e., percentage of total observed broods equals percentage of total wetland acres in the recreation category.
[b] NS = No significant difference in brood use between the two categories at the 5% level of error.

Two races of Canada goose winter in the Basin, the large western (Great Basin) *B.c. moffitti* and the smaller *B.c. taverneri*. *Moffitti* breeds throughout the intermountain west and is the only goose to breed in central Washington. Wintering populations of *moffitti* in the Basin are composed of local birds supplemented by short-distance migrants from other parts of eastern Washington and southern British Columbia and Alberta.

Taverner's goose breeds throughout the interior of Alaska. In fall, Taverner's gather near the tip of the Alaska Peninsula, then depart in groups across the sea to landfall at Skagit Bay in Washington. Most of these continue eastward across the Cascade Range near Stevens Pass. In mid to late October, thousands of Taverner's funnel through Wenatchee River Valley, crossing the Columbia River near Wenatchee. Many head eastward to the Grimes Lake-St. Andrews or Banks Lake areas, but the majority congregate on Stratford Lake east of Soap Lake, Washington. From Stratford, the geese disperse throughout the Columbia Basin and into the Umatilla region of Oregon. Approximately 80 percent of the Taverner's population winters in the Columbia Basin and adjacent areas (Bellrose 1976) [6].

Migration timing and patterns have been fairly consistent for wintering geese and ducks in central Washington, with allowances for weather effects on mallards. However, the size of the fall flight into the Columbia Basin Project area has not been at all consistent over the years. Before irrigation entered the picture, Grant, Adams, and Franklin Counties hosted less than 30,000 wintering ducks, based on early January counts. Until 1959, winter populations of ducks increased slowly; then, the population mushroomed to over 600,000 birds by 1964 (fig. 2.17). Peak counts of ducks occurred throughout the Northwest (Washington, Oregon, Idaho) in 1963

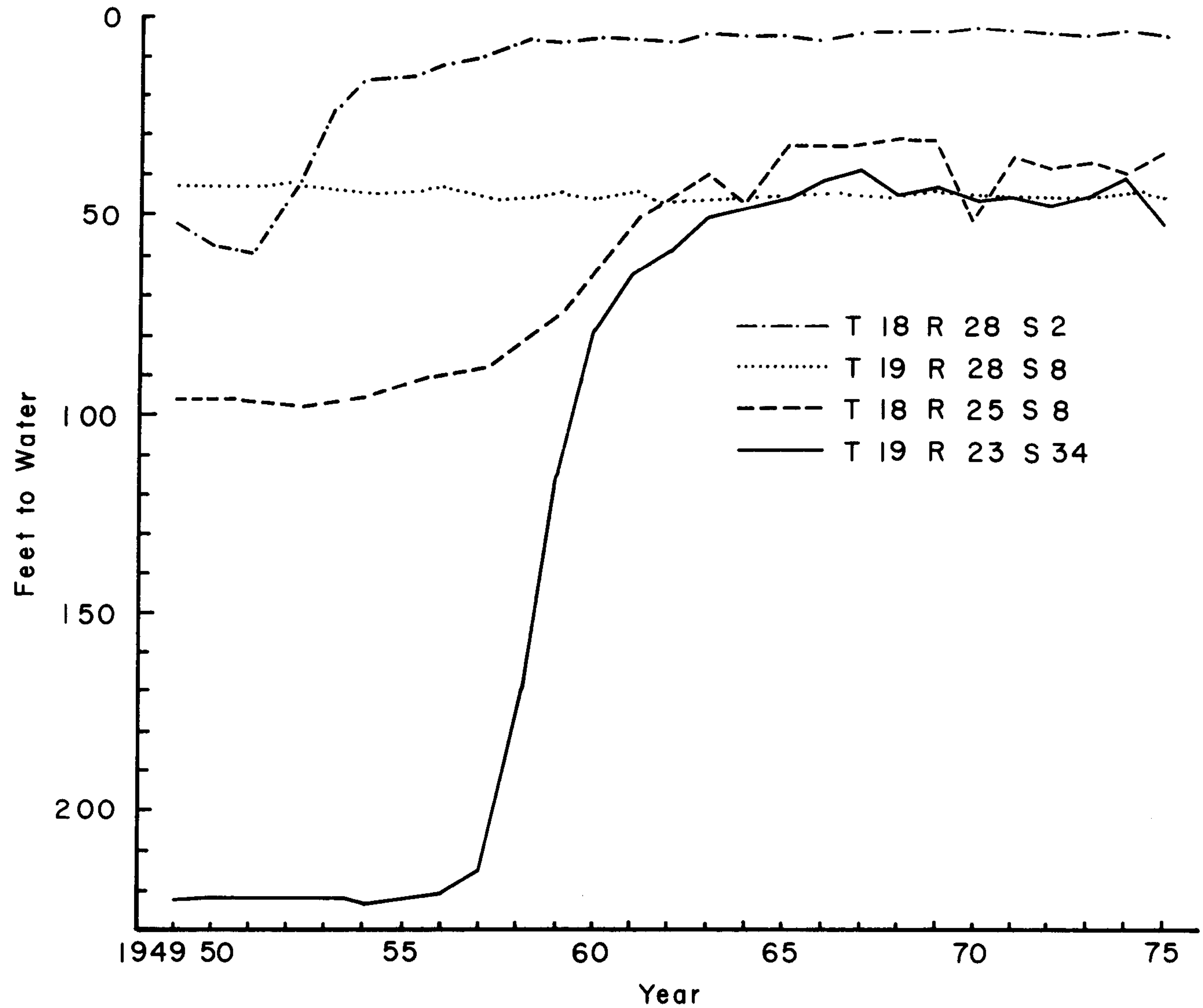

Figure 2.13.–Test well records showing changes in ground-water levels since the beginning of irrigation development in the Columbia Basin, Washington. Data from Bureau of Reclamation, Ephrata.

with over 2,000,000 birds. Most of the increase occurred where a combination of large water areas and adjacent irrigated farmlands became available. This was particularly interesting since continental breeding duck populations were relatively low at that time (Pospahala *et al.* 1974) [49].

Lauckhart (1961) [50] attributed the increase in Washington's duck population to improved winter habitat, and argued that the population must have previously been limited by a lack of quality wintering areas. Populations have remained relatively low and remarkably stable in other parts of the State outside of central Washington. The increases in ducks in central Washington were largely mallard increases; mallards comprise 95 percent of all wintering ducks in the Columbia Basin.

After the all time high of the mid-1960's, wintering populations began an erratic, but definite decline in the Basin. As can be seen in figure 2.17, there was close conformity in yearly variances between Statewide totals and the number of ducks in the Basin from the peak of 1964 on through the decline to 1975. In succeeding years, the Basin's wintering ducks continued to slide, while State totals failed to follow suit. This suggests a possible redistribution of the population, an aspect which will be dealt with later.

Pacific Flyway mallards have been declining for several years. Given this, it is no surprise that wintering ducks are also declining in the Columbia Basin. However, declines in the Basin have been more pronounced relative to that of the Flyway. Opinions vary

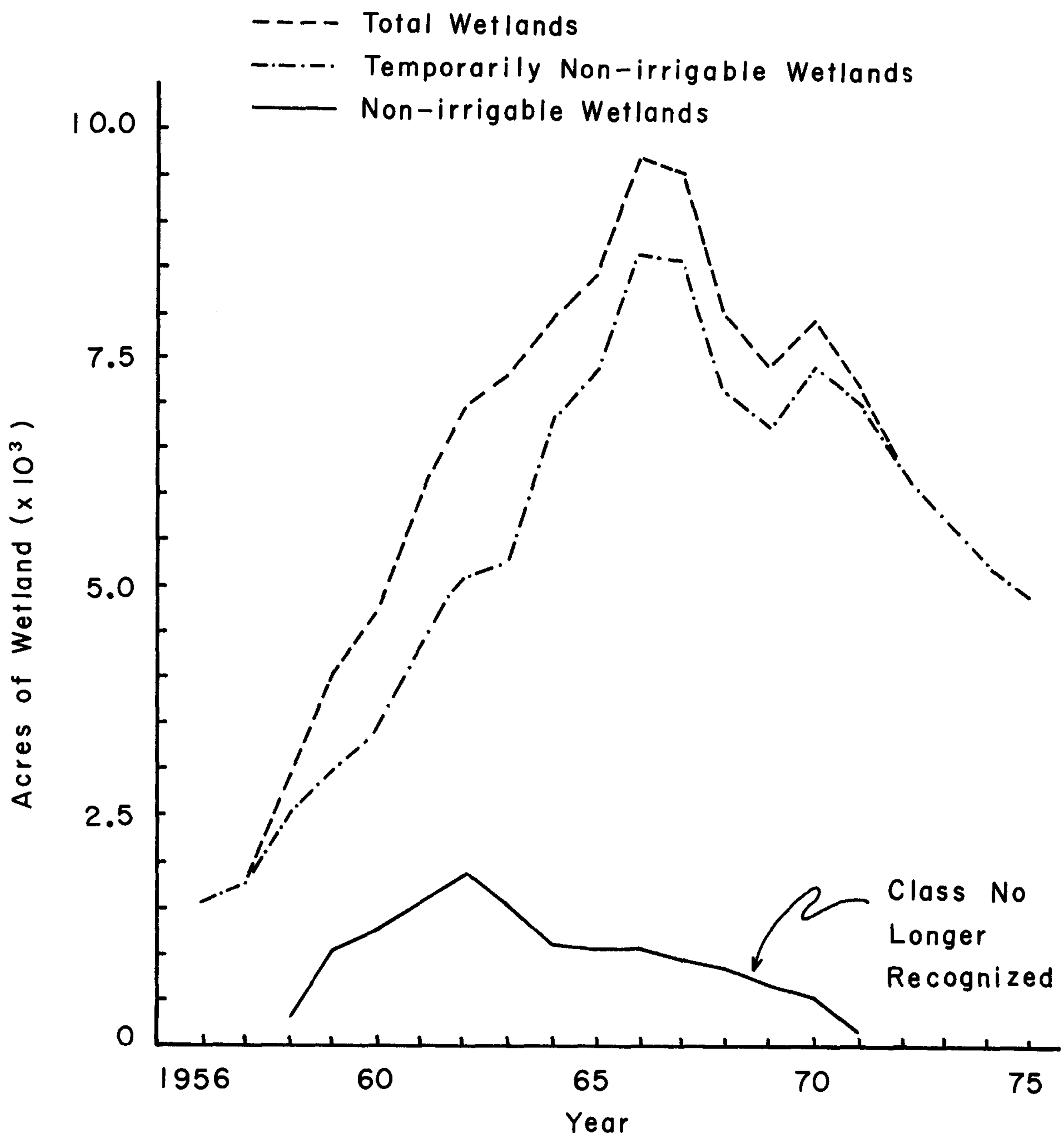

Figure 2.14.–Acres of wetlands within irrigable lands of the Columbia Basin Irrigation Project. Although drains were constructed soon after wet areas first began to appear, new wetlands formed faster than drains could be installed until drainage problems caught up in 1965. Data from Bureau of Reclamation, Ephrata.

as to the cause, but no studies confirm or refute the various explanations. Certainly, factors affecting production on northern breeding grounds have direct impact on wintering populations in the Basin. But this aspect is beyond the scope of this report. Independent research is currently addressing this issue.

In spite of known declines, waterfowl harvests have remained relatively high (fig. 2.18). However, it is difficult to reconcile such harvest levels with other population indicators that reveal diametrical trends. Several hypotheses have been suggested to account for the disparity, but none have been rigorously tested.

Factors Affecting Winter Populations

Food Resources

Considerable professional and public opinion attributes the number (or at least the distribution) of wintering mallards to the availability of field corn. The

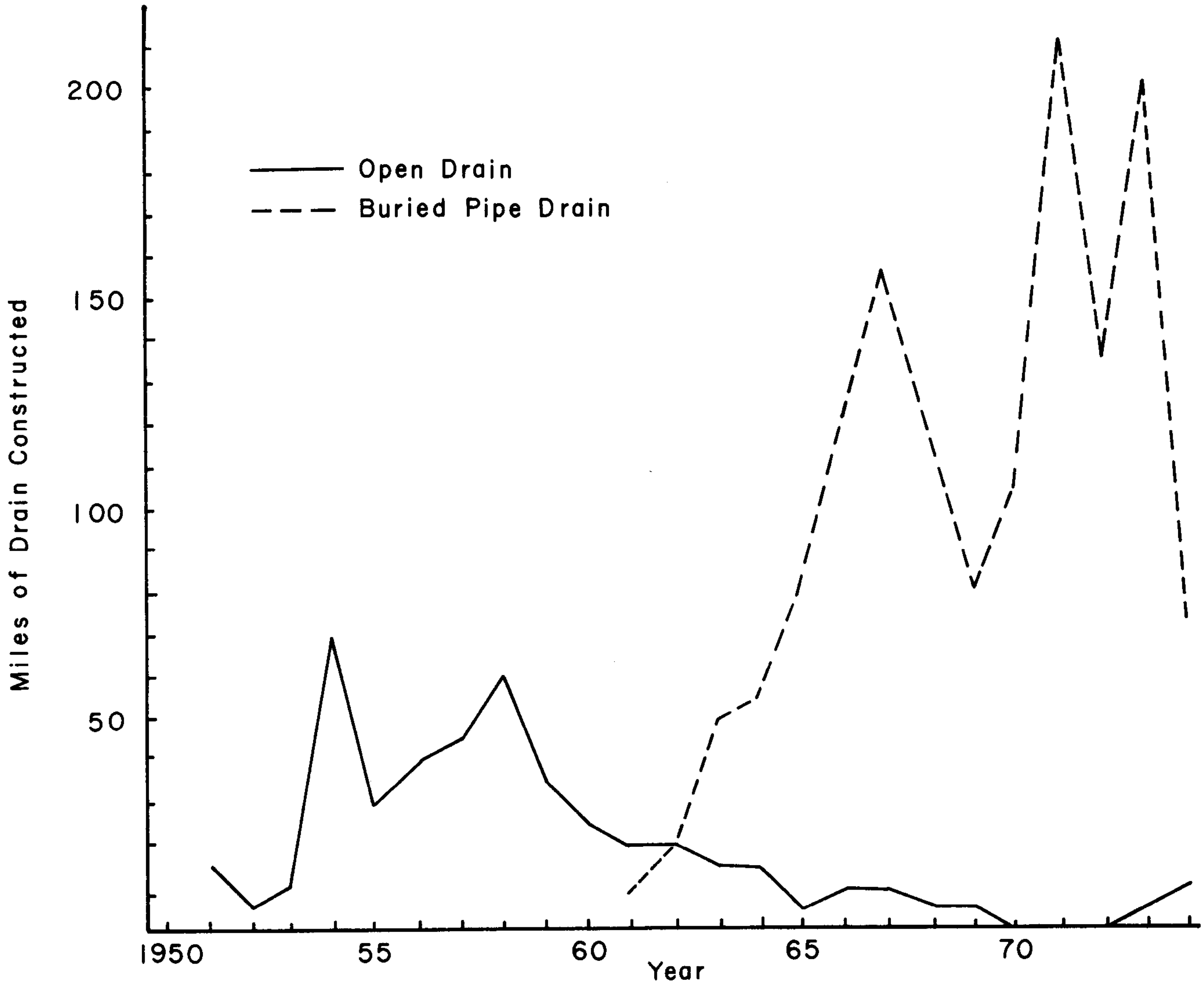

Figure 2.15.–Miles of drains constructed by year on irrigable lands of the Columbia Basin Irrigation Project. Data from Bureau of Reclamation, Ephrata.

general belief has been that field corn acreage has been decreasing, causing ducks to move elsewhere in search of winter food resources. However, no simple relationship exists between corn acreage and mallard counts. Mallard numbers have largely been asynchronous with corn acreage (fig. 2.19). Peak numbers in the mid-1960's came at a time when the amount of corn was very low. In recent years, the mallard population has continued a sharp decline, even though the number of acres of corn was greater than at any time in the history of the Columbia Basin Project (fig. 2.19). Clearly, corn acreage alone does not correlate with changes in wintering duck numbers, as has been noted by Cleary and Lobdell (1978) [51].

The time at which field corn is harvested has been thought to have a strong bearing on duck numbers. In earlier years, field corn was harvested after it had dried in the field. Usually, the desired moisture content was not attained until late December or January. But, in the late 1960's, farmers gradually began to cut corn earlier (October) and completed the drying process in kiln sheds. Throughout the 1970's, increasingly more corn has been removed from the field and dried this way. Whether this practice has sufficiently reduced the availability of corn to cause the tremendous drop in ducks seems doubtful. Early cutting of corn does not appear positively correlated with duck declines. Duck use of cornfields seldom starts in earnest until after mid-October, the time when harvests begin. A sample of 93 mallard crops taken during the 1978-79 hunting season indicated that during October, wheat was the major diet component, with corn occurring in very limited amounts. After October, however, almost no wheat

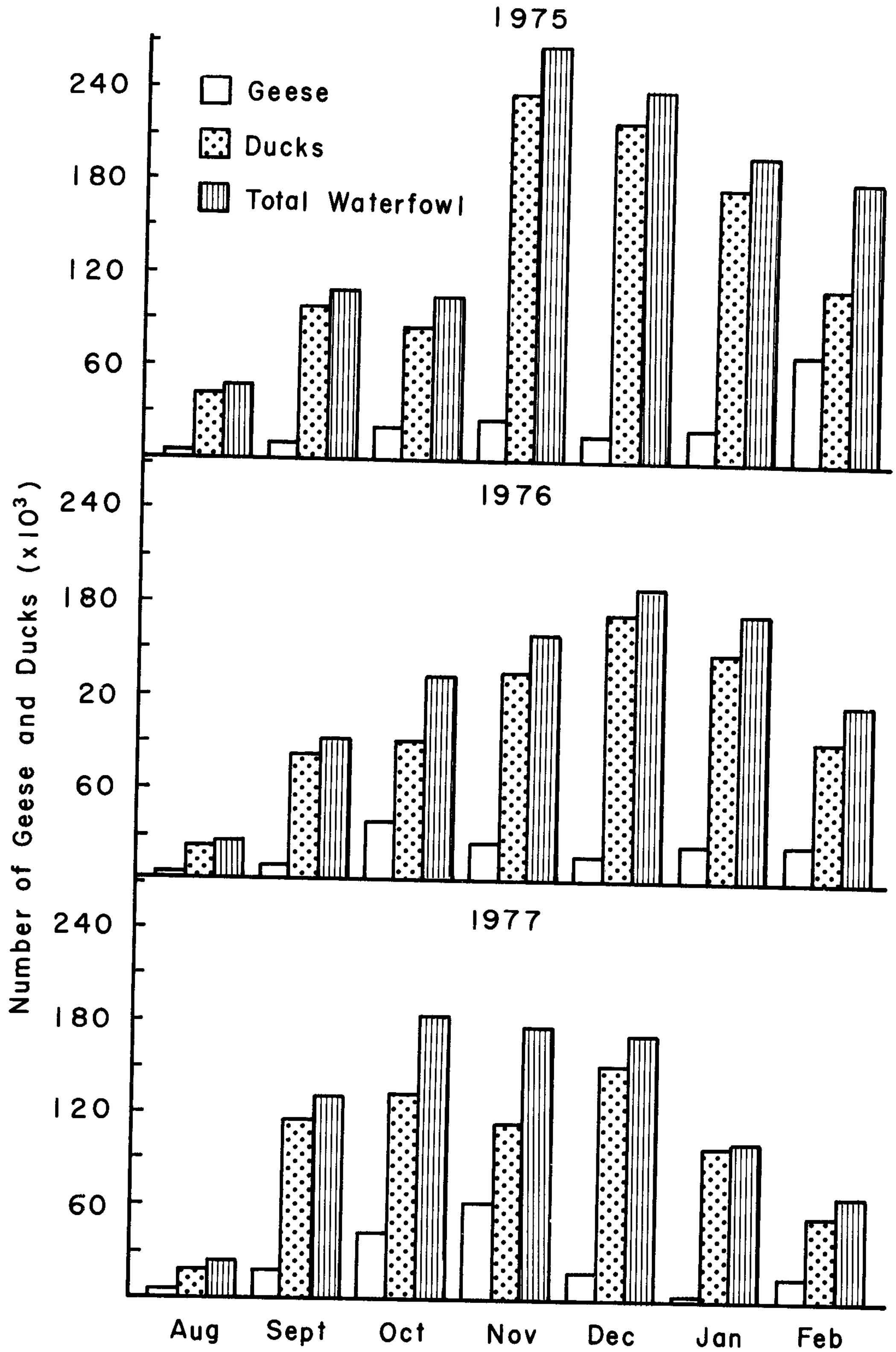

Figure 2.16.–Total number of ducks and geese counted by month on all waters in the Columbia Basin, Washington, during late summer through winter, 1975-1977. Counts were made from aircraft.

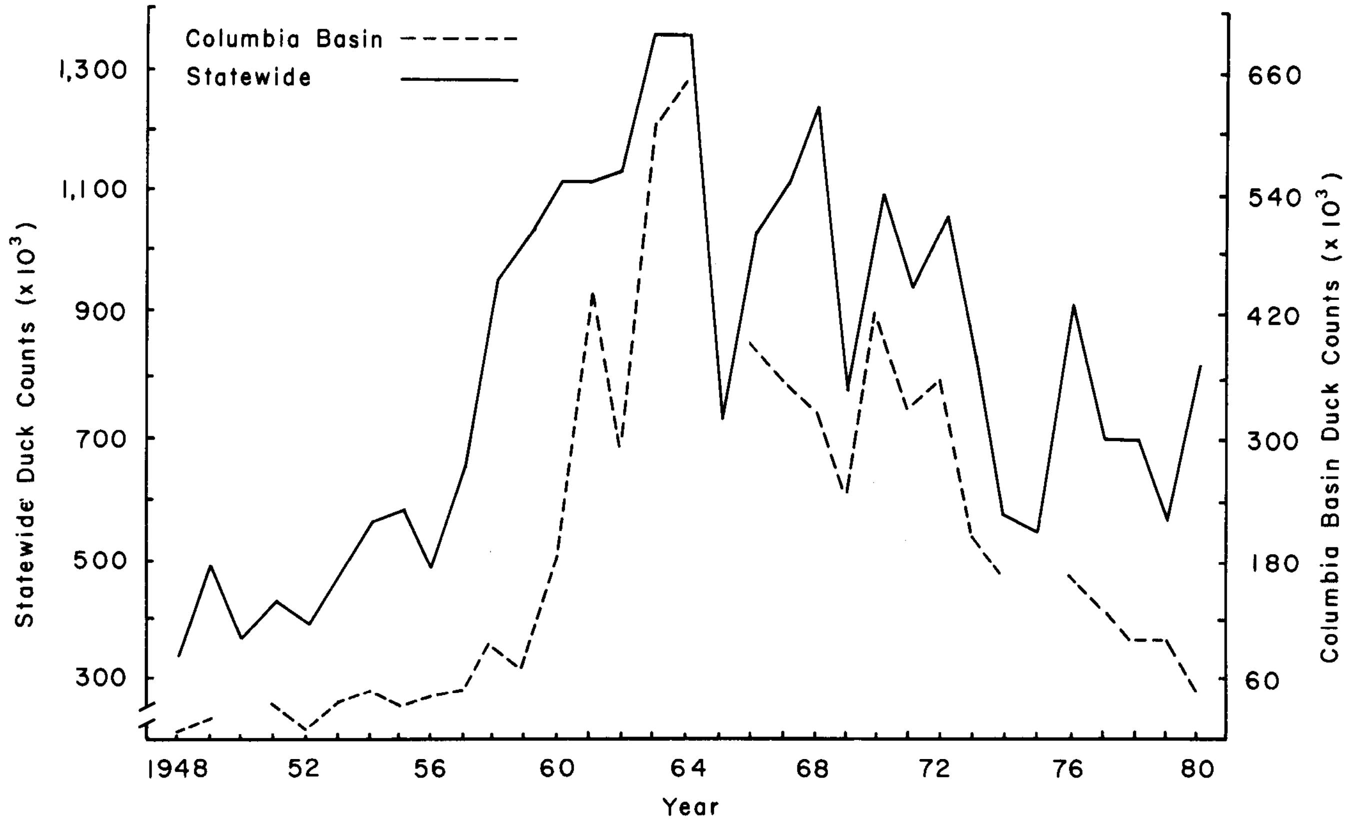

Figure 2.17.–Comparison of State-wide and Columbia Basin, Washington, duck counts during January 1948-1980. Counts were made from aircraft.

was consumed, and corn became the principal cereal grain food (Rabenberg and Regen 1979) [52]. Wheat again became increasingly important to ducks near the end of January and on into early spring. The late-winter switch from corn to wheat was mainly by female mallards. Sex ratios significantly favored female mallards where field feeding on waste wheat was observed. Trapping stations on Columbia National Wildlife Refuge had little success in capturing females until some traps were baited with wheat in place of corn.

Observations of field feeding habits during 1976-1978 suggested a possible preference by mallards for ungrazed, combined cornfields whereas little winter use of standing corn was observed. However, during periods of snow cover, ducks readily used currently grazed cornfields. The ducks apparently relied on cattle to expose waste corn and to knock down standing corn. Later, more intensive work by Ball and Rabenberg (1981) [53] confirmed these observations. They found that cornfields comprised 95 percent of 221 upland field feeding sites, and that 84 percent of these sites were machine-combined stubble. During the two winters of observation, less than 1 percent of the feeding sites were in standing corn.

As a food source, corn alone cannot meet metabolic needs of ducks. Rabenberg and Regen (1978) [54] forced penned mallards to subsist solely on corn. They observed an 11-percent weight loss in the ducks over a period of 2 weeks. Obviously free-ranging ducks in the Columbia Basin must obtain dietary supplements, but as yet, the kind and origin of other foods have not been specifically identified.

Wetland Ownership and Basin Type

Fall and winter populations were most numerous on Federally owned wetlands and least abundant on wetlands in private ownership. Mean densities of ducks per wetland acre and per 1,000 feet of shoreline were 5.5 and 3.0 times greater, respectively, on Federal wetlands than on State wetlands (table 2.1). Nearly all observed use by geese was associated with Federal wetlands.

These results differ significantly from those found for spring and summer periods (table 2.1). Physical structure of a wetland appeared to have some influence on duck use (table 2.2), but this is believed more of a quirk in the data than a real selective difference. Physical and biotic characteristics of a wetland play a minor role in wetland use by wintering ducks

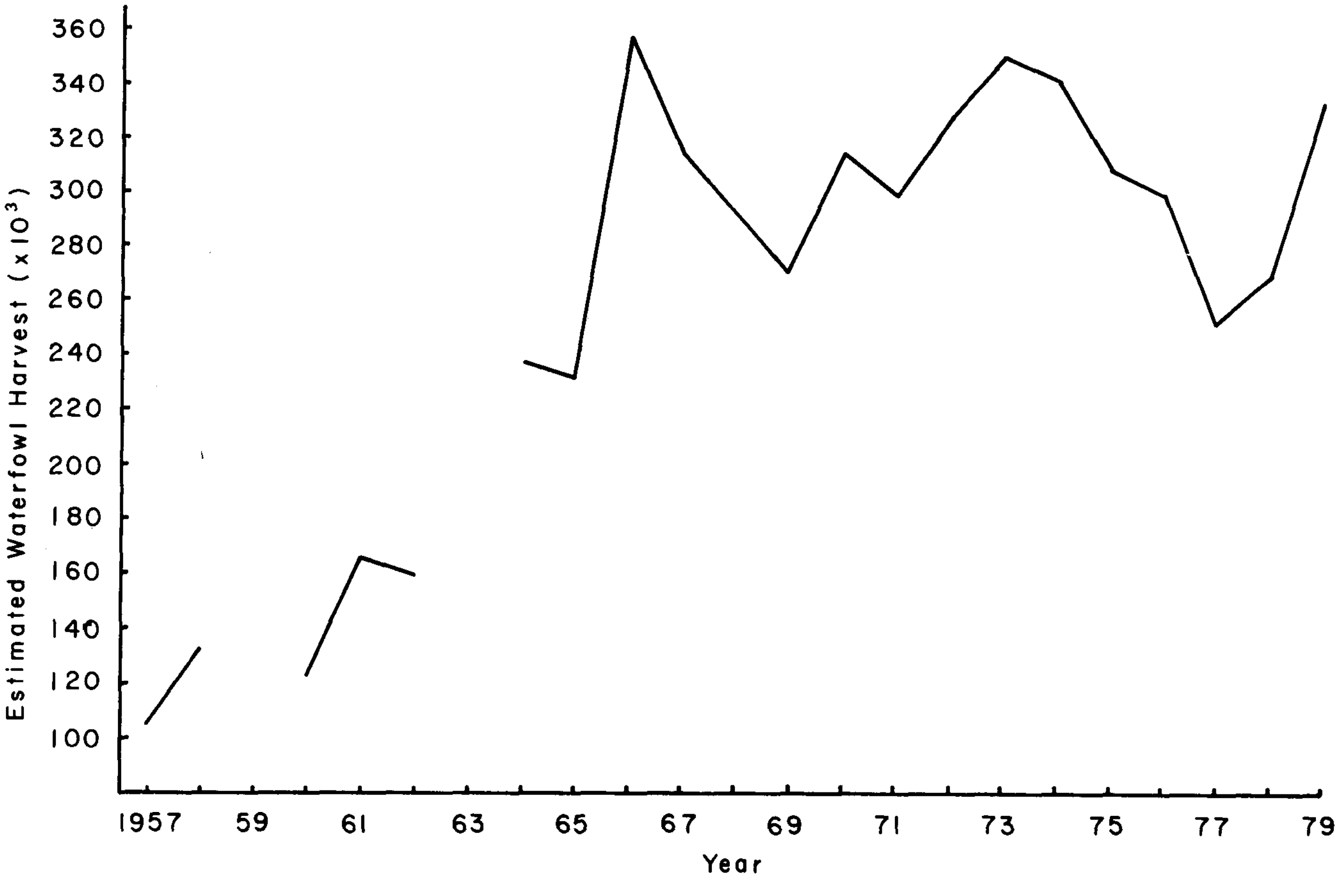

Figure 2.18.–Annual harvest of waterfowl in Grant, Adams, and Franklin Counties, Washington, as estimated from hunter questionnaires.

in the Columbia Basin. Of major importance is the relative intensity of hunting pressure. Figure 2.20 shows the changes in duck and goose concentrations from August through February. Note that prior to the beginning of hunting season (mid-October), the number of ducks was much higher on State-owned wetlands than on Federal waters. Thus, at least until the hunting seasons close, duck concentration areas tended to be those which offer maximum protection from disturbance. Wetlands which provided protection were either large water bodies or managed under legal restrictions on hunting. With a few exceptions, most of the heavily used study waters in fall and winter were owned by the Federal Government, where hunting is tightly restricted.

Livestock Grazing and Carp

Highest densities of ducks were observed during fall and winter on wetlands which were grazed and on wetlands which contained carp. These findings differed from spring and summer results (tables 2.3, 2.4). The switch in use that appears in fall and winter should not be interpreted as a preference by ducks for grazed wetlands or carp-infested waters. Again, the changes appear related to protection from disturbance with biotic factors being of lesser importance. Most of the large water bodies contained carp, and they were also grazed by livestock.

Public Use

As might be expected, wetlands which sustained little or no public use during fall and winter were heavily used by waterfowl. However, where hunting and/or fishing occurred, average duck densities per acre were only 4 to 8 percent of that seen on wetlands unused by recreationists in winter (table 2.5).

Disturbance appears to be the key factor limiting waterfowl use of most wetlands during fall and winter, at least prior to ice-up. Most large water bodies are open to public hunting, but the large amount of open water generally provides a secure distance from hunters. Nevertheless, as hunting pressure increases on a given water, disturbance in the form of power-boating rafts of ducks, herding, or just the movements of restless hunters gradually exceeds the tolerance levels of ducks. Consequently, fewer birds use the big waters each year. This is especially evident in Grant County.

Management policy of State wetlands has in the past centered on the concept of maximizing recreational

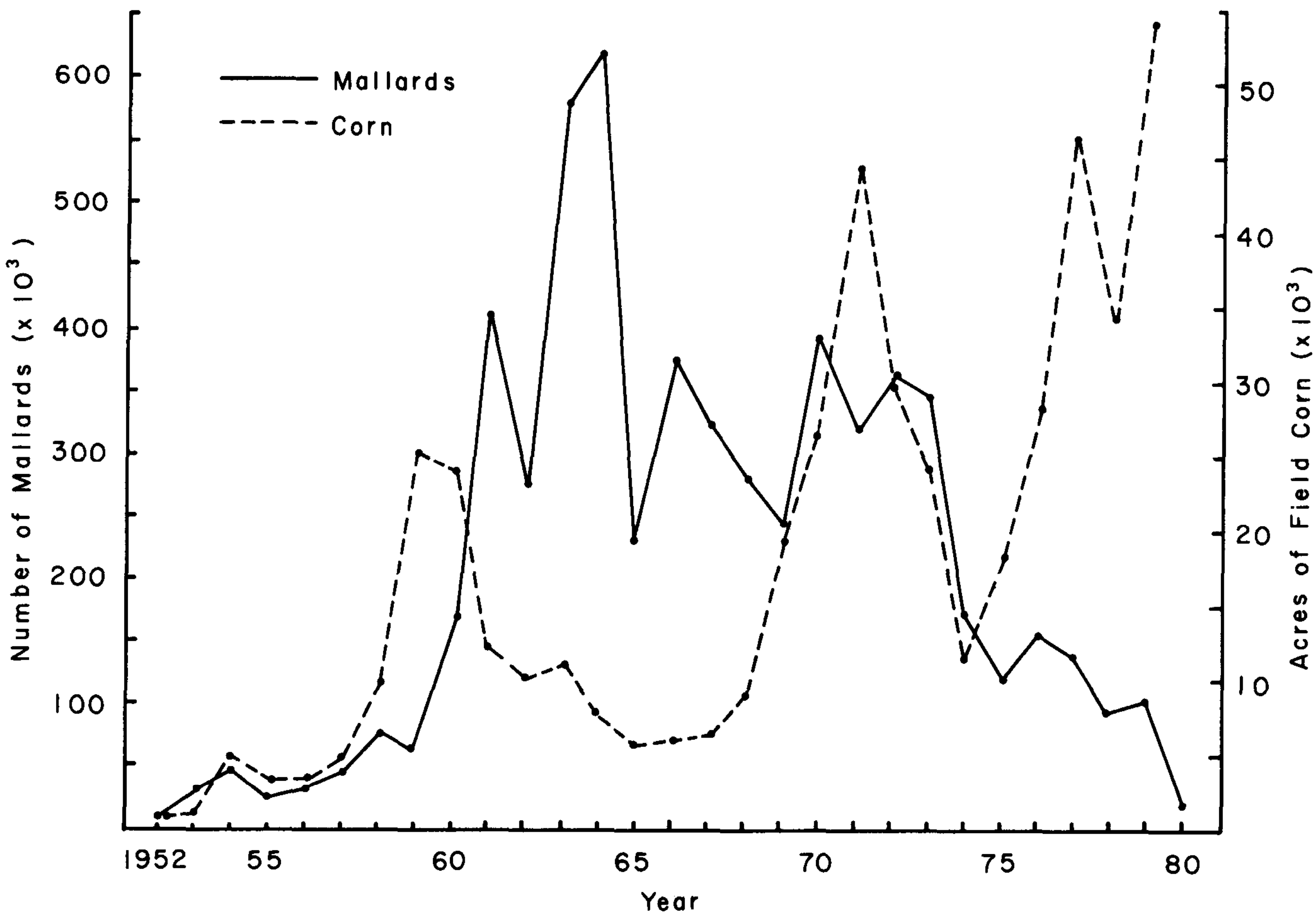

Figure 2.19.–Number of mallard ducks counted in the Columbia Basin, Washington, during early January compared with acres of field corn planted in the Columbia Basin Project, 1952-1980.

opportunity. To attain this objective, State lands were opened up and roads and parking areas provided for hunters. Man-days of hunting became the measure of management success.

This philosophy of unlimited entry or access to State waterfowl wetlands had intuitive appeal and was a popular response to decreasing availability of hunting on private lands. State lands took up some of the slack as hunters searched for new places to hunt. But the effect on waterfowl was not immediately evident. Within a few seasons, waterfowl concentration patterns began to change. Wintering areas became more restricted in the upper part of the Basin and more of the winter population began to drift southward to the relatively disturbance-free areas on Hanford and Umatilla-John Day reaches of the Columbia River. Data on five areas extending from northern Grant into northern Adams Counties indicated that shifts in winter concentration areas were not obvious until the late 1960's (fig. 2.21).

Part of the decline for upper Basin water depicted in figure 2.21 was offset by the construction of Wanapum Dam on the Columbia River. The large reservoir which formed behind Wanapum attracted many thousands of ducks between 1966 and 1974. Thus, at least part of the wintering population translocated west rather than south. Ducks on Wanapum still fed in the grain fields of the northern Project lands.

Yet in recent years, the drain of ducks from northern concentration areas has been particularly discomforting. Wanapum Reservoir no longer holds the numbers of ducks it had prior to 1976. Moses and Banks Lakes retain only a scant handful compared to their heydays of the 1960's and early 1970's. Columbia National Wildlife Refuge has exhibited erratic numbers of ducks in November while Potholes Reservoir had a general decline until the winters of 1979 and 1980. Losses from the upper Basin waters have been paralleled by a rapid buildup of ducks along the Hanford and Umatilla areas of the Columbia River (fig. 2.22). The increases have been particularly large on the Umatilla area. Both areas have tight restrictions on hunting, food in nearby grain fields, and offer the security of large bodies of water to resting ducks.

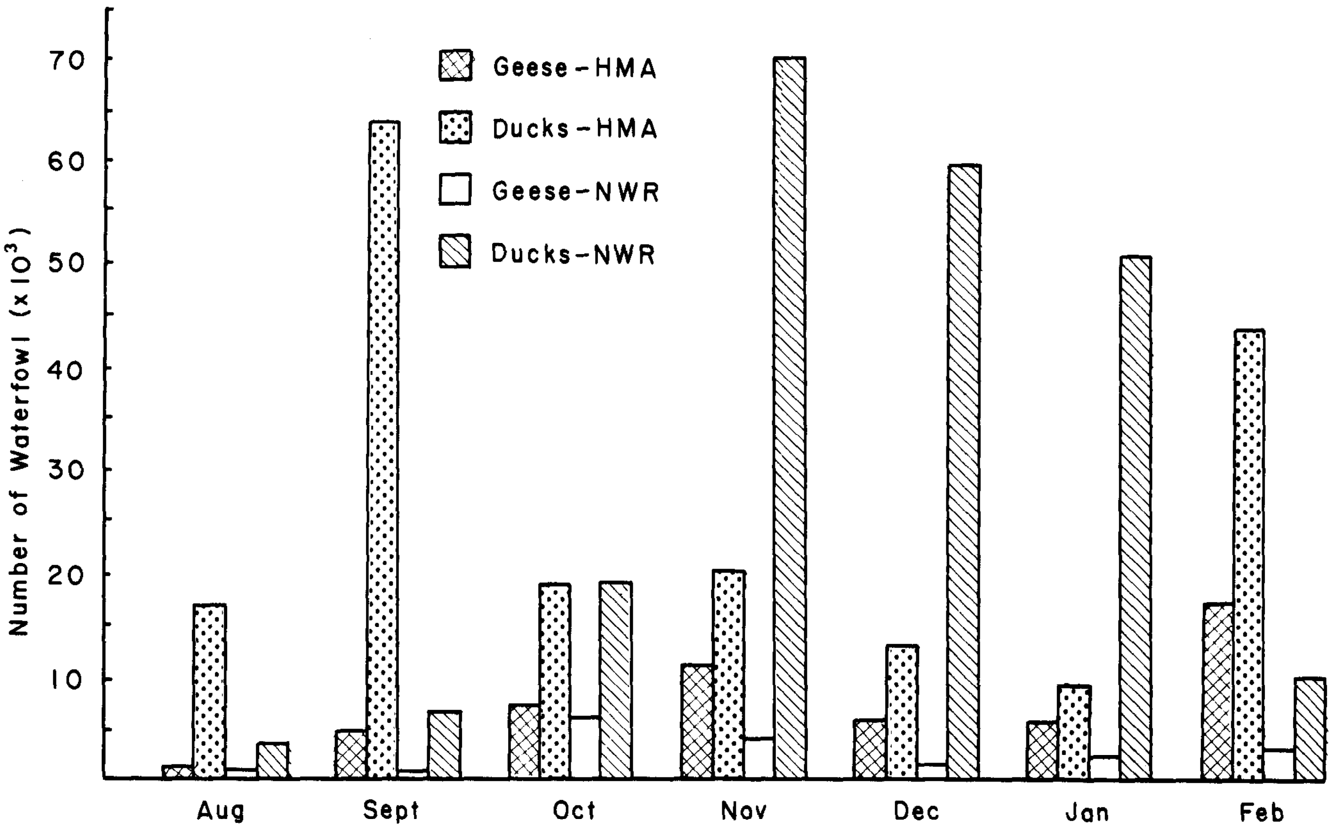

Figure 2.20.–Average number of geese and ducks during late summer through winter for 1975-1977 on all HMA's (State Habitat Management Areas) and two NWR's (National Wildlife Refuges) in the Columbia Basin, Washington.

Waterfowl managers have begun to recognize the effects of disturbance on wintering birds. In 1976 and 1977, three test areas were set up to determine the effect of access restrictions on waterfowl distributions in the upper Basin. Two of these were low-keyed efforts on relatively small areas in which vehicle parking was moved back 0.25 to 0.5 mile from the wetlands. The third was a larger endeavor centered on the north end of Potholes Reservoir. The latter site covered approximately 700 acres of wetlands interspersed among stable sand dunes. A waterfowl reserve was formed and public entry disallowed during the hunting season. Hunting along peripheral wetlands was accomplished by travel of over one-half mile on foot.

In all three tests, waterfowl numbers rose tremendously within the first year of new restrictions. On the two small areas, counts jumped from an average of less that 50 birds to several thousand. Over the next 3 years, ducks used the areas heavily until hunting pressure returned to original levels. The North Potholes unit surpassed expectations. Where only a couple thousand ducks were found before closure, up to 25,000 began funneling in during mid-October. Peak numbers have ranged as high as 60,000 in December and January during ice-free periods. Furthermore, these increases did not appear at the expense of other wintering areas such as Wanapum Pool, Columbia National Wildlife Refuge, and the main body of Potholes Reservoir. In fact, spillover from North Potholes may have augmented counts on other waters in the upper Basin.

SUMMARY AND CONCLUSIONS

Spring and Summer

Ownership has no bearing on whether an area is used by waterfowl. Physical and biological conditions as well as human utilization of a wetland determine its value to waterfowl. Ownership is important, however, for management and preservation of wetlands to ensure continued waterfowl benefits. Public agencies responsible for waterfowl must have authority to preserve and manage wetland habitat, public ownership of at least the majority of wetland areas is a prerequisite to maintaining the waterfowl resource. The continued enjoyment of a large waterfowl population in the Columbia Basin has resulted from public ownership and hence management authority of a large portion of its many wetlands.

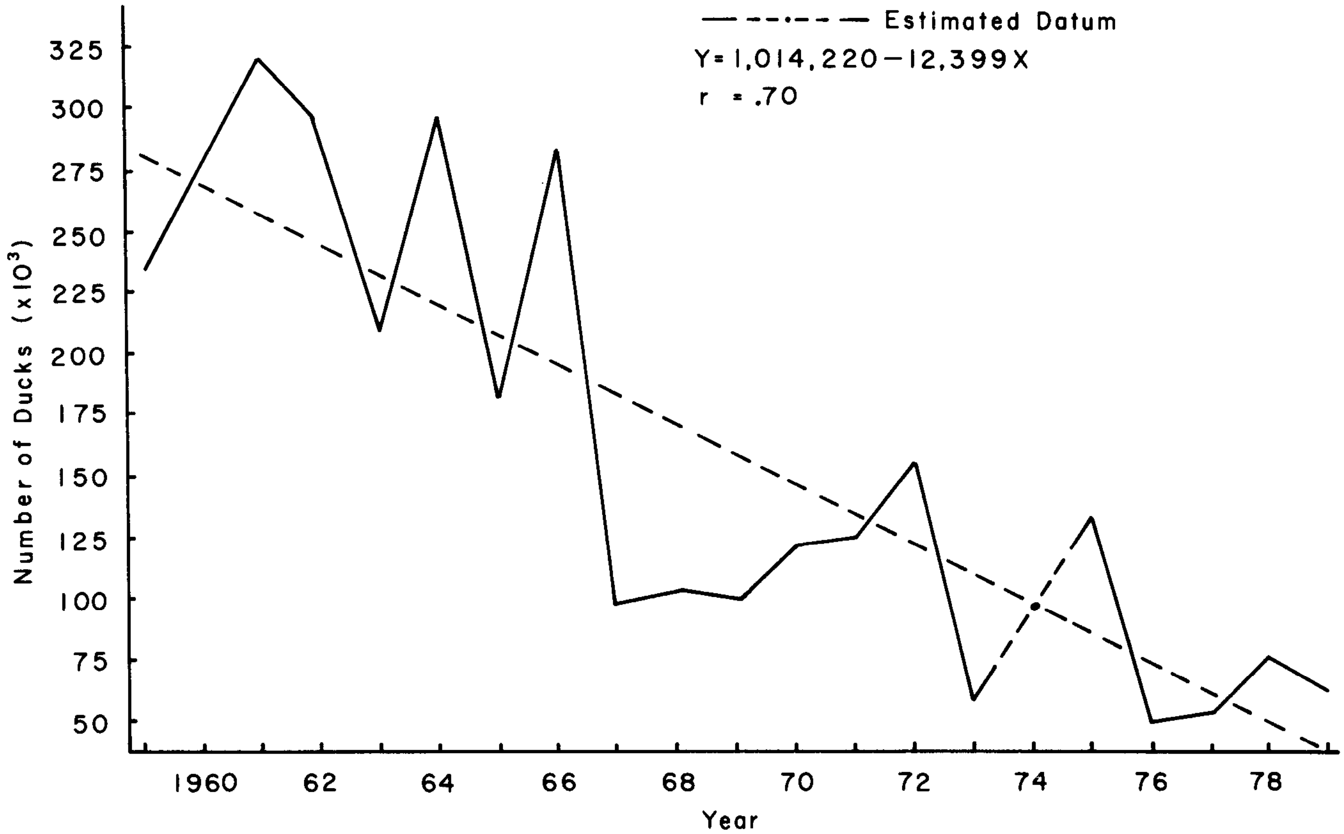

Figure 2.21.–Mid-November duck counts on selected waters of the upper Columbia Basin. Waters included are Banks Lake, Stratford, Moses Lake, Potholes Reservoir, and waters on the Columbia National Wildlife Refuge. Dashed line is the regression of numbers on years.

In the present study, differences in waterfowl use between wetlands of Federal, State and private ownership were evident during the spring-summer period. Several factors were involved. Their effect on waterfowl use of Federal, State, and private wetlands will be pointed out in succeeding discussions.

Where management priorities aim at spring migrant and summer resident ducks, acquisition or development plans should first consider areas of low topographic relief. These areas are likely to provide wetland basins which offer a relatively high amount of shallow littoral area. In the shallow zone, the bulk of a wetland's biomass is produced, and it is here that migrants, breeding birds, and their young forage on abundant aquatic plants and invertebrates.

Scabrock lakes with steep shoreline gradients generally are of less value to spring and summer waterfowl because of a shortage of shallow areas. However, many exceptions to this occur throughout the Columbia Basin. Scabrock coulees often have relatively flat bottoms and may be diked or water levels regulated so as to provide excellent habitat for waterfowl production. Some of the scabrock waters observed in the present study appeared to be potentially good spring and summer habitat for ducks and geese, yet birds were seldom seen on them. Factors believed responsible for waterfowl absence were disturbance (e.g., fishing activities, vehicle traffic), high carp population, and denuded shorelines and upland areas from excessive livestock grazing.

Although no significant relationship was found between wetland size and waterfowl numbers during early spring, duck numbers were heavily biased toward small waters as the season progressed into summer. Breeding pairs sought out smaller wetlands on which to nest and rear young. Brood densities were highest on ponds less than 1 acre in size, but ponds up to 5 acres still yielded relatively high brood numbers.

Unfortunately, small ponds are more susceptible to the vicissitudes of agricultural economics and weather. Changes have occurred in both the number and size of wetlands in the Basin. For ponds of the

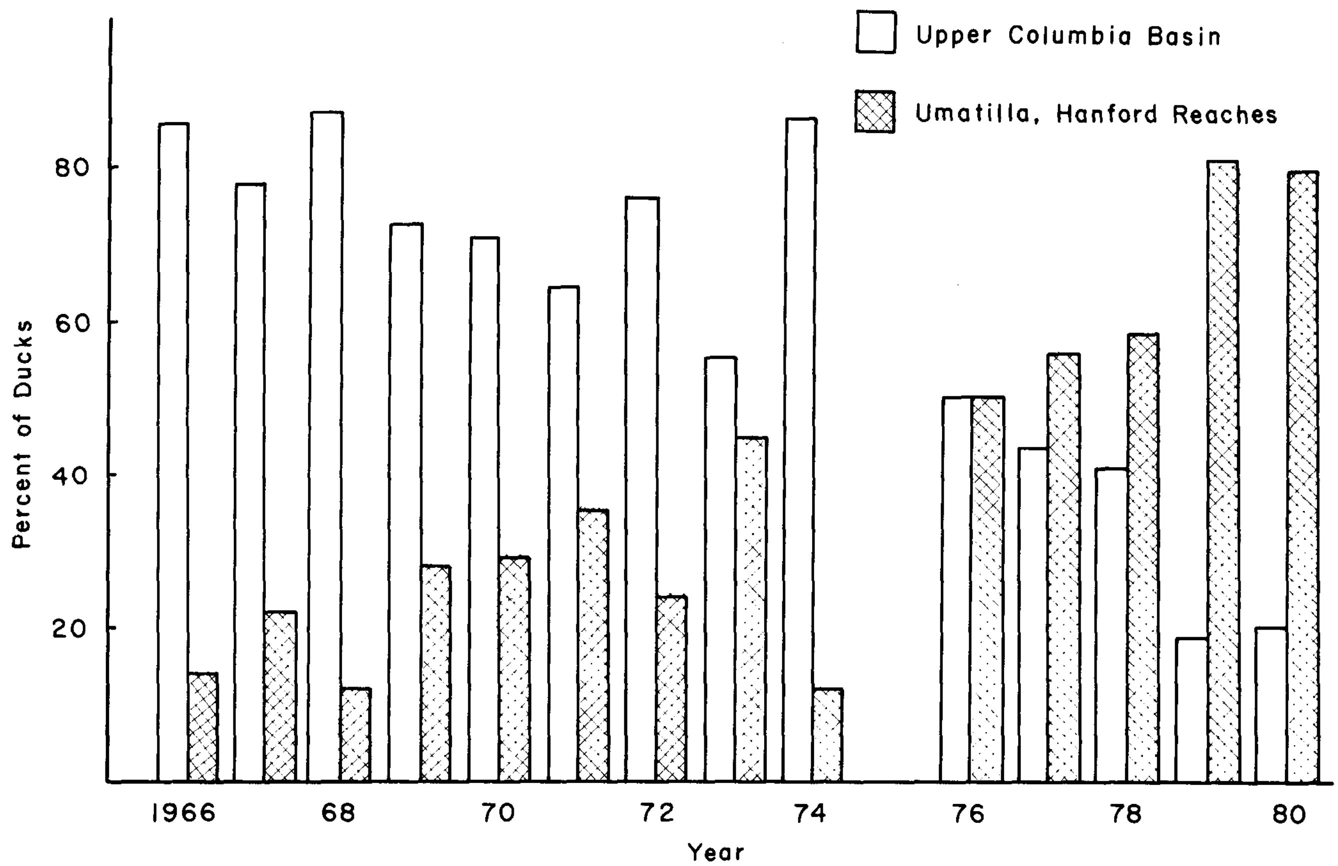

Figure 2.22.–Comparison of mid-November duck counts in the upper Columbia Basin, Washington, with Hanford and Umatilla Reaches of the Columbia River. Upper Basin waters are Banks Lake, Moses Lake, Potholes Reservoir, Columbia National Wildlife Refuge, and Wanapum Pool. Hanford and Umatilla Reaches include Columbia River and adjacent areas below Wanapum Dam to west boundary of Umatilla NWR.

size used most by ducks, net changes are difficult to assess because of varying usage of the word "wetland." To the biologist, a wetland usable by waterfowl is some form of standing water on land surfaces. But to the engineer and developer, a wetland is any place too wet to support an agricultural crop in the Basin regardless of whether or not moisture collects above ground. Existing records do not adequately differentiate between wet soil and standing water.

New irrigation expansions have usually resulted in the formation of wet areas. Some of these have potential waterfowl value if allowed to mature even though they may be little more than a puddle. The high use by duck broods already mentioned emphasizes that large wetlands are not required to grow ducks. This is an important consideration in planning new projects.

Of equal importance, although untested by this study, is the density of the wetlands. Production of waterfowl will likely be highest where many small wetlands are created in close proximity to one another. Brooding hens have a propensity to travel from one pond to another either from an innate wanderlust or to satisfy physiological or other behavioral needs. Areas that support the highest density of ducks per surface acre in North America occur where large numbers of **small** wetlands dot the landscape. If two similar areas with the same total wetland surface area are compared, the one sprinkled with individual ponds will produce many more ducks than the area containing all its waters within one or a few large basins. The literature provides ample evidence to support this concept (Dzubin 1969 [55], Gilmer *et al.* 1975 [56], Dwyer *et al.* 1979) [57].

Canada geese generally inhabit the largest lakes and impoundments of the Project area, and the majority of nesting occurs on such waters. The large lakes contain islands, the choice nesting site for geese. They also offer the security of distance providing a sanctuary from ground predators. Small ponds lack these characteristics. Geese are well adapted to the relatively oligotrophic environments of big waters since physiological requirements are largely met by upland grazing. Nevertheless, spring and summer populations have become established on some small lakes, ponds, and streams in the Project.

Quite a number of nonriverine breeding geese in the Basin appear to be new or young populations since their occurrence has only been recognized within recent years. Those occurring on the small lakes and ponds in the Project probably originated from outgrowths of populations on impoundments in and near the Project. Except for a few cliff nests in scabland areas, insular nesting is the rule; small lakes which lack islands are unused by breeding geese. Successful goose nesting has been observed on islands in ponds as small as 10 acres.

Too few temporary lakes were contained in the study sample to reliably describe their use by waterfowl. Complete desiccation of ponds has little impact on total production in the Basin at present. However, based on present trends of declining water levels on the Winchester-Frenchman Hills wetlands, temporary wetlands may become a critical factor in duck production. Most areas containing surface water follow a hydrological cycle which coincides with but yet is independent of precipitation patterns. Wetlands unconnected to irrigation distribution systems obtain water through seepage or increases in ground-water tables. Ground waters are recharged annually from percolation losses during crop irrigation. Extensive pumping from wells to operate center-pivot sprinklers has heavily capitalized on high-ground-water tables and may be a contributing factor in lowering surface water levels near Winchester and Frenchman Hills Wasteways. However, counterarguments ascribe phreatophyte withdrawals and general evaporative losses as the leading causes of surface water declines. As described in the aquatic section, declines in flows of Winchester and Frenchman Hills Wasteways seem to be more closely related to water level declines of nearby ponds and and marshes than do ground-water withdrawals. Nevertheless, plans for ground-water use in the Basin have suffered from poorly understood ground-water dynamics. Consequently, management of the resource has been based on supposition and political expediency. The questions surrounding ground-water management should be resolved in view of the multipurpose functions credited to irrigation development.

Ponds greater than 3-foot maximum depth drew brood-rearing ducks during late spring. Duck numbers were high on shallower marshes in early spring but regressed in favor of deeper waters as summer approached. These changes were directly related to decreasing surface area of wetland and to a lesser extent to the gradual encroachment of cattle into marsh vegetation as water receded.

Marshes over 3 feet deep were usually able to maintain sufficient open water to be attractive to ducks throughout the summer. Highest summer use by duck broods was on wetlands which contained 25 to 75 percent open water. Many marshes and shallow ponds in the study area were essentially closed habitats. Approximately 34 percent of the wetlands occurring along Project wasteways are overgrown with cattails and bulrushes (i.e., 10 percent or less open water). Use of these wetlands by ducks was limited to early spring when water levels were highest.

Three study ponds on which water levels were monitored became closed habitats during the course of this study. Water levels dropped nearly 2 feet in 5 years.

Many of the closed wetlands could be made productive of ducks if dense stands of cattails were opened. Heavy, concentrated grazing, use of herbicides, explosives, and to a lesser extent fire are alternatives for vegetation control. The most effective control of emergent plants can be attained through water-level manipulation. This requires installation of regulatory structures and is advised wherever feasible. However, many wetlands occur in closed basins which may be impossible or impractical to drain.

From midsummer on into early fall, duck broods were almost exclusively found on ponds which contained abundant submergent vegetation. Despite similar physiochemical characteristics, many flatland waters contained few or no submergent plants. Lack of submergents was directly related to presence and abundance of carp. Removal of carp is one management effort which can substantially increase waterfowl use and production on many Basin waters. Although widespread recognition of the negative impacts of carp on waterfowl exists, management in Washington has been slow to apply the knowledge. Purchase of rotenone is almost nonexistent for waterfowl purposes. Likewise, dikes, fish screens, semipermeable barriers, drop structures, and the separation of irrigation return flows from spring creeks have not been used as widely for enhancing waterfowl production as they have to provide carp-free waters for gamefish. Many Project wetlands are amenable to one or more of these alternatives at low cost to management agencies. Moreover, these enhancement measures would impose no additional liabilities to agricultural operations.

Of paramount concern for new irrigation developments is the separation of water delivery and return flow systems from spring creeks and static waters that originate from seepage. This aspect never entered the planning of the existing Project design and, consequently, has been one of the basic limitations to sustaining high fish and wildlife populations. Potentially productive spring creeks nearly always become contaminated by undesirable fish when delivery or return flows flow into these streams.

Present management of livestock grazing on public lands in the Columbia Basin has generally been detrimental to ducks and of limited value to geese. Until now, the impacts of grazing on Columbia Basin waterfowl were undocumented; yet, grazing programs were imposed and defended partly on the basis of entrenched beliefs that grazing benefited wildlife. Just how wildlife were benefited was not often clear. Demands from livestock interests and the need for additional revenues may have contributed to grazing allotments. On some lands, however, the issue had been decided in land purchase contracts which obligated long-term grazing rights to the original owners.

Grazing can be a most useful tool in managing waterfowl habitat in specific situations. It can also be a most destructive agent when misapplied. To obtain waterfowl benefits, each area must be considered independently. Variations in vegetation type, density, and amount of foliar cover in relation to waterfowl nesting needs should guide the process of determining specific grazing programs: intensity (AUM's), season, duration, and target plant species. In many situations, a reduction in emergent aquatic plants (i.e., provide more open water) may be all that is necessary. For the semiarid Columbia Basin, indigenous upland vegetation seldom needs to be grazed since it rarely attains densities unfavorable to upland nesting duck such as mallard, teal, and gadwall.

The close-cropped vegetation associated with livestock grazing is favored by foraging geese. This fact is sometimes used as an argument for initiating grazing programs on public wildlife lands. We find fault in this argument for two reasons. First, where grazing might be an asset for geese, it becomes a liability to upland nesting ducks. Second, grazing yields benefits to geese only in rather specific areas. During spring and summer, geese benefit from cattle grazing mainly where it occurs near **established** nesting areas. As far as small lakes and marshes are concerned, livestock use will provide virtually no benefits except on the very few areas where geese nest. Even then, benefits are questionable; successful nesting and brood rearing have been observed on waters where cattle were absent. Many of the study wetlands supported livestock but did not seem to attract geese. The majority of grazed wetlands were never used by geese during any period of the year. It may well be that managers have lent undue credence to livestock grazing as an enhancement measure for geese.

The results of this study showed that grazing during any season of the year had negative impacts on waterfowl use and production. Overall, the least impacts occurred when grazing seasons ran through winter and early spring months. Nevertheless, grazing should be approached with caution. Mallards, an early nesting species, depend primarily on residual vegetation for nest cover. Winter grazing may remove or trample beyond useability the bulk of upland plant residue. This appears to have been the case on the study areas. Most of the production from winter grazed wetlands was by redhead and ruddy ducks.

Inability to control livestock numbers, duration of grazing, and trespass grazing has plagued managers for years. Either an increase in management personnel or a reduction in the number of permits could alleviate the burden and allow more attention to effective management of existing leases, as well as policing of illegal grazing activities.

The main problem facing managers is conflict in management programs. Livestock grazing involves one such conflict, but nowhere is conflict more evident and more serious than in the issue of public use of wetlands. Waterfowl clearly need protected areas at all seasons of the year. Yet managers are faced with public pressures to provide more and easier access to ducks, not only during the hunting season, but also for nonconsumptive viewing in spring and summer. The situation is further complicated by the establishment of intensive spring fisheries on many Basin lakes and ponds which generally occur at a time when ducks begin setting up breeding territories.

Recently developed management plans portend still more habitat losses if the plans are enacted. Some elements of the plans call for providing more areas for fishing, hunting, and nonconsumptive uses. Fish introductions on former waterfowl areas, new roads, parking areas, trails, boat launches, and the expansion of agreements with private landowners to allow greater public access form a substantial part of the new management plans. But our findings indicate that most of these plans will prove detrimental to not only waterfowl, but other wildlife as well. More appropriately, managers should consider increasing the number of waterfowl reserves and reducing the ease of access on much of the public waterfowl wetlands. Certainly, all conflicts between waterfowl production and the competing uses of fisheries and nonconsumptive recreation can never be completely eliminated. As in the past, some wetlands potentially productive of waterfowl may have to be sacrificed for other uses. However, sacrifices and conflicts can be reduced through cooperative and innovative management approaches.

Conditions most conducive to goose nesting are generally well known: relatively large lakes with islands permanently separated from shorelines.

Goose pastures nearby are beneficial, but usually do not require intensive developmental measures. Most geese do well on natural cheatgrass ranges if precipitation patterns provide moisture for plant growth at the time when goslings need it. On occasion, winter drought may cause cheatgrass to mature too early; by goose hatching time, all that is left are dry seed heads and culms. Under normal or above average precipitation, spring livestock grazing may be desirable to reduce tall growth. Goose pastures need not be large; seldom does an entire wetland need to be grazed for the sake of geese. Cattle grazing should be restricted to parts of each wetland to ensure that adequate nesting substrate remains for ducks.

Nesting success for geese runs 80 percent or more as a result of their choosing isolated nest sites and generally high attentiveness to the nest. By contrast, the success rate of ducks in brood production falls well below 50 percent as shown in this study. Success in duck nesting depends on the persistence of hens and the efficiency and abundance of predators. Most nest failures appear to be a result of disruption by predators; 38 percent of all nests found in this study were destroyed by predators. However, it was not certain if predators actually caused initial disruptions. In any case, destroyed and deserted nests were most common in areas of poor quality cover or where dense cover was restricted to very small areas.

The best deterent to predation losses, and possibly "voluntary" desertion as well, is the provision of large, undisturbed tracts of tall, dense vegetation. Nesting in the strips of vegetation associated with canal banks and roadsides is not only low, but yields virtually no production because of predators. Most of the nesting attempts seen in this study were in the wet soil zone bordering wetlands, an area which supports primarily sedges and bulrushes. In the majority of wetlands examined, this zone varied from 0 to 50 feet in width. The wet soil zone is analogous to the artifically created strips along canals and roads, and nests situated therein are subject to similar predation risks. Numerous studies have shown that predation and desertion losses of duck nests tend to be much lower where high-quality cover occurs on fairly large tracts of land with wide retangular to square configurations, as opposed to relatively narrow strips. Undisturbed blocks of nesting cover should be at least 20 acres in size, but preferably larger. Vegetation height must be greater than 12 inches to be suitable for upland nesters; less than 12 inches results in virtually no nesting use (Malcolm 1981) [58]. The amount of canopy coverage provided by plants should apprcach 100 percent, although lesser densities are acceptable if nesting ducks are free of disturbance. Less than 50 percent canopy coverage generally becomes unsuitable for mallard nesting.

A particular plant species has little meaning to would-be nesters. Ducks are opportunistic; they will utilize whatever plants offer the best cover, preferably in a disturbance-free environment and near water. Therefore, plans for improving or creating duck nesting cover need not be concerned with so-called vegetational cover preferences. Any ecologically adapted mixture of broadleaf forbs and grasses is acceptable if they meet the specifications for height and canopy coverage. During years of normal precipitation, cheatgrass ranges do not provide sufficient height or residual litter, even when ungrazed, to be of value for nesting. Crested wheatgrass, widely used on ditch banks and roadsides, may be tall enough most years, but is too sparse to attract nesters. Shrubs are also acceptable (e.g., sagebrush, rabbitbrush, bitterbursh, greasewood), provided the stand is sufficiently open to permit growth of forbs or grasses in the interspaces. Very dense stands of shrubs and tall, densely matted forbs offer no utility to upland nesters. Agricultural crops contribute little to duck nesting in the Project because of late season growth habits, mechanical disturbance, or remoteness from brood-rearing habitat. Some nesting occurs in winter wheat and alfalfa where these crops border watercourses and static wetlands. Unfortunately, most cropland nests fail to produce young because of distruptions during harvest or by other human disturbances.

Since the majority of duck nesting occurs near (< 100 feet) static wetlands, management steps should aim at providing the best possible conditions in these areas. Undeniably, ducks will nest farther away if cover is unavailable around wetlands, but duckling survival decreases with increasing distance from water. Some researchers have found nests over 1 mile from water. At the extreme, Duebbert (l969) [59] suggested that hens in North Dakota may fly as much as 3 to 5 miles from water to nest in high-quality cover. However, nesting at such distances from brood-rearing habitat severely limits duckling survival; almost none of the young are likely to survive the overland journey to water. But Duebbert's point is well made: "*Nest site selection can be influenced favorably by the manipulation of land-use patterns or vegetative growth forms.*" If waterfowl managers provide high-quality nesting cover close to brood-rearing wetlands, much higher nesting success and duckling survival than presently experienced are assured.

Fall and Winter

The dependence of wintering ducks on Columbia Basin corn crops has been poorly understood. This study and the work of Rabenberg and Regen (1979) [52], however, have provided new insight to mallard-corn relationships.

High winter duck populations in the northern part of the Columbia Basin Project have been attributed to the abundance of field corn. Certainly this has been a factor, but declines or egress from the North Basin (area north of State Highway No. 26) do not appear at all related to abundance of field corn (fig. 2.19). Major shifts in wintering areas have sent ducks in unprecedented numbers to southern portions of the Project (Hanford Reach) and to the Umatilla-John Day areas along the Columbia River. These shifts have occurred when corn production in the North Basin has been greater than at any time in Project history.

Combines are the principal means of harvesting grain corn, although a small percentage of farmers still use machine pickers. Harvesting begins in early October in the southern part of the Project when moisture content of the kernels reaches about 22 percent.[2] Grant County corn takes more time to reach low moisture level; consequently, harvest begins and ends later. Combine harvesting is usually complete by the end of November. Some fields, however, may be left uncut and later used for cattle grazing or the corn is left to dry in the field until as late as March and then harvested. Extremely high losses (as much as 30 percent) are incurred by field drying and for this reason nearly all farmers have switched to fall cutting and the use of commercial dryers. At present, only about 2 to 3 percent remains uncut by January. [3] Early cutting has reduced wasteage in the field to between 4 and 10 percent (average 6 percent).[2]

Using an average wasteage of 6 percent, and an estimated yield of 125 bushels of corn per acre, approximately 420 lbs. of corn per acre is left on the ground in the wake of the combines. Expanded over the Basin, wasteage on 54,000 acres (Bureau of Reclamation 1980) [60] amounts to over 11,000 tons of corn. Not all of this is available to wintering ducks. Approximately 10 to 15 and 35 to 40 percent of the stubble fields are burned and grazed, respectively. Burned fields are rarely used by ducks. Stubble being grazed is important, for the most part, only during periods of deep or crusty snow cover. The remaining stubble fields (50 percent) are disked, of which 30 percent may be turned under within 2 weeks after harvest. Once the ground freezes, undisked stubble is left until spring; 30 percent or more of the ungrazed and unburned corn stubble may remain well into spring.[2] Thus, at least 4,000 tons of waste corn in ungrazed fields and about the same amount in grazed stubble may be available through the winter. Most of this occurs in Grant County.

[2] J. Benson, personal communication.

[3] M. Rabenberg, personal communication.

Ungrazed corn stubble seems to be the most attractive to field feeding ducks from late October through January during normally mild conditions. At present, the amount of fall cutting and disking does not appear to have reduced corn stubble availability below wintering needs of ducks. Thus, the argument of not enough corn in the north part of the Project appears invalid.

Aside from possible production declines on the northern breeding areas, weather patterns and harassment seem to be the prime factors influencing wintering ducks in the North Basin. Duck responses to weather have been outlined earlier. Except for the winters of 1968-69 and 1978-79, there have been no significant changes in either onset or length of freeze-up periods or in amount of snow cover. Even so, birds have steadily drifted away from the north part of the Project. Only within the last 3 years have the North Basin populations hinted of a comeback – this as a result of providing a few refuge areas for resting birds.

In earlier years, Wanapum Pool on the Columbia River and the main body of Potholes Reservoir complemented the functions of Columbia National Wildlife Refuge. Several hundred thousand ducks found little disturbance on these areas. Unfortunately, increases in hunters and boat traffic gradually began to erode these natural sanctuaries until only Columbia National Refuge remained.

Wanapum Pool serves as a good example of just how little disturbance it takes to cause mallards to abandon an area. In the 1960's and early 1970's, only a handful of waterfowlers hunted birds upstream from the mouth of Quilomene Creek. Tens of thousands of ducks swarmed into the "big water" during the pre-dawn twilight after spending the night in corn fields of the Quincy Basin. Gradually, word got around of the good hunting on Wanapum. But hunting the large pool required different techniques and equipment from what most hunters of ponds and marshes were accustomed. Large decoy spreads were a must. So were larger "seaworthy" boats equipped with 20- or more horsepower motors to handle rough water and travel the long distances from launch areas to hunting sites. Hunting big waters was thus a capital intensive endeavor which deterred many waterfowlers. As a result, large waters such as Wanapum Pool were somewhat self-limiting; the number of hunters grew slowly. In 1979, an estimated two dozen parties hunted Wanapum on any given weekend. For a water extending over 20 miles in length and up to 1 mile wide, it is relatively low in hunter density compared to smaller Basin waters.

Even though hunters were few, the sanctuary effect of big water was destroyed largely by boat traffic:

hunters retrieving cripples, relocating to different sites, or simply returning to the boat launch. Added to this was the infrequent harassment of power-boaters disrupting large rafts of resting ducks. Gradually, ducks began to avoid the Crescent Bar-to-Quilomene stretch upriver and instead began to pile up near Vantage and in the forebay of Wanapum Dam. But within a few short seasons, even this wide, open expanse of water began to lose its attractiveness. At present, ducks can still be found there in large numbers for a few days in November during the height of migration. Thereafter, the birds exit south to the Hanford area and along the Umatilla area to John Day Dam reach of the Columbia River.

A strong trend has appeared on Wanapum which shows that migrating mallards are bypassing the pool altogether: fewer birds are homing to the Wanapum reach each winter. At the outset, most of the egress was caused by disturbance. But in the last few years, continued human activity on Wanapum and, perhaps more importantly, the imprinting of young migrants to a different wintering area have combined to lessen the use of all large waters of the North Basin.

New, attractive wintering areas have developed along the Umatilla to John Day reach. Thousands of acres of new corn circles (center-pivot irrigated fields), the warm water of cooling ponds for steam generators at Boardman, Oregon, and the huge refuge area on the Columbia have all aided in syphoning off the North Basin duck population. The situation can be reversed, at least partially, by two management changes. First, hunting restrictions must be relaxed on the Columbia River at Umatilla Refuge. This would tend to break up some of the huge concentrations of birds, forcing them to seek other sanctuaries. To lure them back northward, waterfowl managers must provide several refuges in the North Basin. Both measures should be done in tandem to obtain the greatest benefit. However, of the two, North Basin sanctuaries are the most critical. This has already been demonstrated by the newly created North Potholes Reserve.

Most of the factors which influence spring and summer use of various wetlands appear to have little significance during fall and winter. Distribution and size of the waterfowl population in the Project seem to be governed more by the need for quiet resting areas than any other factor. Food does not at this time appear to be a significant limitation to Project area ducks.

Refuges or reserves must have guaranteed water rights – sufficient water to attract and hold a desired number of waterfowl through the winter. Recent changes in water storage in Potholes Reservoir threaten to eliminate the North Potholes Reserve as a very effective wintering area for some 60,000-70,000 ducks and geese. The change in water regime will reduce water levels in many large ponds in and near the Reserve during fall and winter. Many of these will become dry; the remainder will contain too little water to hold wintering birds. Although the Project is advertised for supplying multiple benefits to the public, planned water management favors irrigation interests exclusively. Future water developments must incorporate binding contractual agreements that assure adequate water for waterfowl throughout the year.

RECOMMENDATIONS

Land acquisitions for wildlife should never be made which contain long-term grazing rights or any other land-use encumbrances.

Water rights must be assured by not allowing any institutional or private entity to withhold or deny purchase of irrigation water or prevent the use of other ground and surface waters which may exist or be developed on a wildlife land parcel.

Minimum and maximum water levels acceptable to both wildlife and irrigation interests should be established on important breeding and wintering waterfowl areas.

Ground-water withdrawals for irrigation is a crucial factor which could be detrimental to waterfowl wetlands. Ground-water dynamics are poorly understood and, therefore, need to be studied in detail before allotments are given near areas used by waterfowl.

Both static and flowing waters of seep origin should not be connected to irrigation watercourses at any time of the year to prevent ingress by carp and influents of suspended silts and organic matter from croplands and cattle feedlots.

Water-level regulatory devices should be installed in static wetlands wherever possible to control growth of cattails, produce waterfowl food plants, prevent establishment of carp, and lessen risks of botulism.

New wetlands which develop as a consequence of irrigation (those originating from elevated ground water or seepage) should be retained in public ownership and managed for waterfowl and other wildlife.

Where wetlands are to be constructed for spring and summer resident waterfowl, areas of low topographic relief should be considered first because of the relatively greater littoral area they provide.

Static wetlands under 10 acres in size will provide the greatest return in duck brood production.

It is strongly recommended that nesting islands be provided in all wetlands to reduce loss of duck nests to predators and to increase goose nesting.

Large, undisturbed areas near wetlands are needed for upland nesting ducks. Ten acres should be considered as minimum, and 20 acres or more ideal. Nesting plots should be designed in wide rectangle or square configurations as opposed to long, narrow strips. Minimum widths should be at least 100 feet. Nesting areas must be protected by fences and irrigated and fertilized as necessary for maintenance.

Vegetation plantings for nest cover should provide 100 percent ground cover at heights not less than 15 inches. Plant species selection should be guided by ecologic suitability, cover and height requisites, and acceptability by agricultural interests.

All habitat development areas should be fenced. Grazing should be eliminated near wetland areas during all seasons of the year. Fenced lanes may be provided where access to water is needed by livestock. Where goose nesting occurs, small goose pastures can be developed on shorelines through cattle grazing, but these grazed areas should never exceed more than one-half of the shoreline perimeter.

Terms of existing grazing leases are frequently exceeded. Trespass grazing is also a common occurrence. Both problems could be eliminated by adding more enforcement personnel, realinement of work duties, or a reduction in the number of grazing permits.

Weed control should be limited to spot applications when herbicides are used. Broadcast spraying should be used only where noxious plants dominate large areas.

Wetlands which contain less than 25 percent open water because of vegetation (mainly cattails) encroachment should be opened up. Heavy, concentrated grazing, use of herbicides, explosives and, to a lesser extent, fire are alternatives for vegetation control. The most effective control of emergent plants can be attained through water-level manipulation. This requires installation of regulatory structures and is advised wherever feasible.

Carp should be removed from waterfowl-breeding and brood-rearing areas. Diking, rerouting of feeder channels, installations of various fish barriers, and use of piscacides should be used wherever carp become established in streams and small wetlands.

More large reserved areas must be established in the Columbia Basin. A portion of all new wetlands must be maintained as waterfowl breeding and wintering areas, completely free of human uses such as fishing, boating, wildlife viewing, and hunting.

On some waters such as Wanapum Pool or Potholes Reservoir, alternative hunting patterns should be tested. Rather than the current allowance of hunting every day, agencies should try limiting the number of shooting days to 2 or 3 days per week. Test periods should not be less than 4 years to give wintering birds time to adjust, and to allow for yearly variations in migrant populations.

A number of other approaches to curtail harassment of wintering birds should be tried to improve wintering duck numbers in the North Basin: eliminate mechanically powered boats on some waters, encourage more walk-in hunting, and limit the number of shot shells a hunter may possess in the field.

Provide incentives to private landowners to develop duck nesting cover along wetlands.

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Chapter III

PHEASANTS AND IRRIGATION DEVELOPMENT

Joseph H. Foster

PHEASANTS AND IRRIGATION DEVELOPMENT

Columbia Basin history is short on terrestrial wildlife records. Sage grouse were abundant during early settlement, but began to wane as cattle and agriculture spread. Similar declines occurred with the white-tailed jackrabbit, and also the pygmy rabbit. Jackrabbits were so numerous as to be regarded as a crop-devouring plague; great rabbit drives were instigated to rid the farmlands of them. By the time irrigation entered the scene, rabbits and sage grouse had all but disappeared.

Except for a few early-day ornithological expeditions, nothing is known of the variety and population status of other terrestrial animals. Even during the first half of the Project's existence, field studies were too few and inadequate to yield anything indicative of populations. Interest in nongame wildlife by institutional and governmental entities has arisen only within the last decade. Yet no attempts to measure populations or to understand the relationships between agriculture and nongame wildlife have occurred. It could be said that most wildlife species flourished while a few native species declined as a result of irrigation development.

The ring-necked pheasant was introduced to the Basin partly as replacement for dwindling native upland birds. Although the birds became established, their numbers remained relatively low until irrigation water began wetting crops in 1952. As the Federally funded irrigation waters flowed over greater and greater areas, the pheasant population grew, soon spreading to all corners of the Basin. Between 1962 and 1966, the number of pheasants peaked and then began an alarming decline. At present, the pheasant population appears to have stablized, or at least has been declining at a low rate.

When this study began in 1975, concern over the sharp downtrend was strongly voiced by landowners and management agencies, as well as hunters. Because of this concern, research plans were developed to discover what environmental and developmental factors were most important in managing pheasants of the Columbia Basin Project. Both positive and negative influences on pheasant populations were to be documented. This information was then to be used in the planning stages of new irrigation developments in eastern Washington. Thus, new irrigation, where subsidized by Federal money, could be developed and operated with an eye to wildlife, in addition to formerly single interest use by agriculture.

METHODS

Study Site Selection

In accordance with the research proposal and contract (Bureau of Reclamation Contract No. 14-06-100-8885), six general land-use classes formed the basis for study site selection. These six classes were combined in the study proposal into two categories: "naturally occurring habitats" and "artificially created habitats." These two primary categories were further defined for study purposes as were the six general classes, the details of which are given in appendix B.

Selection of sites for the terrestrial portion of the study began on existing project lands. Subsequent sites were selected outside the project to fulfill the needs of land use classes as outlined in appendix B. Study site selections were made on two levels for lands within the Columbia Basin Irrigation Project: (1) by irrigation blocks, and (2) by square-mile sections within irrigation blocks. Irrigation blocks were selected primarily on the basis of wildlife production levels obtained from information gathered by Washington Department of Game personnel, including hunter bag check data, pheasant crowing counts, harem counts, and road kill surveys. Productivity for each block was ranked on a relative scale of good, poor, medium, or unknown. Approximately equal samples of each were selected. Square-mile sections within each chosen irrigation block were selected randomly. Sampling rate within each block was approximately 10 percent of the total block area.

Difficulties were encountered in adhering strictly to this scheme because lands devoted exclusively to wildlife production are not evenly distributed over the Basin project. Further, 1-square-mile study sites did not often fall entirely within the bounds of these lands under the selection procedures employed. To meet the intent of the study proposal, study plots were to be wholly within wildlife lands. Thus, some variance to the stratified random approach was necessary.

Analysis of data in 1976 indicated additional sites were needed in some land-use classes. During succeeding years of field work, a few sites had to be reclassified because of classification error or actual changes in land use.

Field maps for the Columbia Basin were developed from small scale topography maps and aerial photography made available by the Bureau of Reclamation at Ephrata. Maps of sites in Yakima Valley were drawn on overlays of aerial photos supplied by the U.S. Agricultural Stabilization and Conservation Service, Yakima. Each technician was assigned several field maps on which he made corrections, descriptions and notes concerning land use, management practices, field boundaries, irrigation systems, crops, idle lands, and amount and kind of noncrop vegetation. Maps were continually updated and refined during surveys from 1976 to 1978.

More recent aerial photography (1978 and 1980) was used to estimate acreages of crop and noncrop lands, as well as the length of rights-of-way. Very small or narrow parcels were measured in the field when information could not be derived from aerial photos.

Pheasant Density Estimates

Transect routes were established on each study section: two routes traversed east and west across a section, each 0.5 mile apart and 0.25 mile from respective north and south section boundaries; two routes running north and south a distance of 0.5 mile on east and west perimeters. Thus, the transect routes formed a rectangle 0.5 mile wide by 1 mile long on the central half of a section. Total length of the route was 3 miles. Routes were modified on a few sites to avoid damage to some crops.

A landowner list was compiled from county records for all study sites. Landowners/managers were contacted for access permission prior to the conducts of field work. Landowners were very cooperative and helpful throughout the study. Access was denied on only seven sections, three of these midway through the second field season, and two prior to fall work during the first year (1976). Denials were made for reasons unrelated to personnel or objectives of this study.

Field personnel were usually employed for a 6-month period and, as a consequence, considerable turnover and training of new personnel resulted. At the start of each season, approximately 2 days of training in field procedures was given to new personnel.

Field observations on wildlife and site characteristics were coded and entered in the field on specially prepared forms. Observations on wildlife consisted mainly of species, number, sex, and age (where possible) and type of vegetation seen in and location of sighting (on section map).

Wildlife data from transects were converted to estimates of density per square mile according to procedures described by Overton (1971) [1] and Anderson *et al.* (1976) [2]. Computations for each site were combined within their respective land use classes pursuant to the directives of the study contract. Analysis of habitat variables were similarly treated by land class.

Nest Studies

Rights-of-way and Idle Lands

Roadsides were grouped according to ownership: Federal, State, or county. Waterways were separated into three categories: main canals, lateral canals, and drains. Two to four technicians participated in nest searches, the number contingent on width of a strip. Four- to five-foot long wooden rods were used to probe and part vegetation to reveal nests.

Data were recorded on nest survey forms and consisted of most common plant species on the area, relative density, vegetation height, and management of vegetation (burning, chemical treatment, mowing, disking, grazing, or undisturbed). Relative to nests, the following information was noted: status, type of vegetation at nest site, location in plot, and number of eggs. Nest status was determined by examining one egg from each nest and by the general condition of the nest. Nests were classified as either hatched, active (hen laying or incubating), abandoned, or destroyed (by predator, man or unknown).

Idle Lands

Idle lands were characterized by lack of soil tillage and excluded rights-of-way, farmsteads, and open water. Survey and data collection procedures were the same as those used for right-of-way studies.

Croplands

Alfalfa, dryland wheat, irrigated wheat, mint, and corn stubble were the only crops searched. Other crops lacked sufficient foliar cover or were grazed too heavily (irrigated pasture) to provide nest concealment.

All dryland wheat was surveyed during the harvest. Irrigated wheat was searched both early in the season and during harvest. In uncut wheat, personnel were spaced about 4 feet apart. A gerry-rigged "T" square constructed from four wood laths was used to part culms. The apparatus proved effective and resulted in no damage to standing wheat. Rill irrigated fields were allowed to dry for at least 1 day so that no damage to corrugations resulted from foot traffic. A few fields were searched during combining in August. Chaff deposits were heavy and required the use of hay forks to obtain better ground coverage. This procedure was deemed of little value in getting reliable estimates of nesting use of wheat. Lateness in the season and heavy chaff accumulations imposed severe limitations on locating nests.

Nest searches in alfalfa were conducted during the first cutting of the season – late May to mid-June.

Two to four persons followed closely behind swathers to find nests before scavengers. Alfalfa mowing generally attracted ring-billed gulls, occasionally ravens and magpies, which quickly capitalized on mice and nests of pheasants and ducks exposed by cutting.

Data entries included nest status, number of eggs, age of embryo (if incubated), presence of hen, fate of hen, distance to nearest edge, vegetation in adjacent fields, type of irrigation system, and type of swather (auger- or draper-type) used.

Field area was determined from onsite measurements or obtained from the farmer. Field sizes, or portions thereof, were sampled in a range from about 3 to over 100 acres. Large fields (over 25 acres) usually required more than 1 day to cut either because of moisture conditions or mechanical breakdowns.

Habitat Use

Habitat use by pheasants was described in terms of frequency of observation within a given vegetation type. Observations on 2,230 pheasants from spring and fall transects routes were considered to reflect relative values of different natural and crop vegetation to pheasants. Locations of radio-marked pheasants during spring through midsummer supplemented early-spring and fall direct observations. General procedures for radio tracking have been described by Swedberg (1981) [3]. Studies on winter habitat use spanned the period of mid-December 1978 through February 1979.

Ninety-five areas of unfarmed lands were searched by one to four persons with the use of dogs. The number of personnel used varied according to the size of the area. Small areas were completely searched. On large tracts where coverage of the entire area was impractical, a sample strip 150 feet wide was covered. Only pheasants seen within the strip were counted.

Unfarmed areas were described as two basic types: (1) rights-of-way which incorporate banks of canals, drains, railroads and roadsides, and (2) idle areas. Idle areas were defined as an uncultivated parcel, exclusive of rights-of-way, open water, farmsteads, road surfaces, and inslopes of irrigation channels.

Areas of study plots were determined from aerial photos and measurements in the field. Sample plots were heavily biased to sites of less than 15 acres size, but this generally reflected actual distribution of unfarmed plots on agricultural lands. Vegetation characteristics of each site were described in terms of dominant cover type.

Each site was classified according to several criteria: land-use intensity of the section in which a site occurred, vegetation cover type, cover quality (good, medium, poor), and area in acres. In addition, presence of livestock and distance to nearest cropland were determined for sites on wildlife lands.

LAND USE CLASSIFICATION

Considerations

Many biologists have accepted as truth the theory that a wildlife population exists at a level commensurate with available habitat. This theory tends to heavily influence thinking such that even population nuances are believed a reflection of subtle differences or changes in habitat. Over very large areas, this theory may be demonstrable, yet it may fail miserably when applied to smaller land units. When such failure happens, we try to compensate by increasing the sensitivity of land classification.

Increasingly complex classification schemes recognize inherent variability in land forms, land use, and other physical conditions. They begin to show probable cause for variations in wildlife abundance – the population is "thus" because of "that."

Even so, the most highly refined and complex classifications cannot account for all the variability in wildlife populations. Some problems in counting (or estimating) wildlife arise independent of habitat variables and sophisticated methodologies; the species in question simply may not appear when and where it theoretically should. Such random error commonly runs high when dealing with highly mobile species, such as pheasants, whose home ranges may include parts of several sections.

In field research, statistical probabilities are also a function of fiscal budgets. Quite often, population estimates or relationships to a land classification scheme fall short of the high levels of precision and accuracy desired.

The system used to classify lands in this study is based in part on the concept of farming intensity; i.e., the degree to which a land area is thoroughly cultivated. The scheme also considers differences in land use which arise as a consequence of private irrigation development, compared to that provided by the Federal Government. The six major classes shown in table B.1 (app. B) are broadly defined. However, further refinements are distinguished within each class. Originally, subclasses were developed from several physical features evident on a given site. These features, or characteristics, varied significantly from site to site for a specific land class.

Because of this variation and the extensive nature of the study, it was impractical to obtain equal samples of each characteristic. Further, it was impossible to isolate a sample of square-mile sites which exhibited only one of the various physical features. This, coupled with variability in the size or amount of a given characteristic, precluded any meaningful analysis on a subclass basis. Even between the major classes there was an element of interaction. No large blocks of land fell exclusively within, say, the B_1 class. Almost invariably, one or more other land classes either bordered a B_1 (or B_2) site or occurred within 1 mile of it. This is a critical concern when attempting to relate wildlife populations to differences in land use. Tables B.2 and B.3 in appendix B show six of several physical features examined in this study. Rank depicts variability of each feature by land class. One can easily see an exponential growth of the number of study sites if equal sampling rates were applied to each rank and land class.

Class Distinctions and Similarities

The sole criterion separating intensively farmed and multipurpose sites was a matter of 15 acres or more of untilled land. If a square-mile study site (section) had less than 15 acres of untilled land, the section was classified as intensively farmed. Multipurpose sections were those with higher amounts of untilled area. Thus, many other features were found to be represented on all land classes. Reference to tables B.2 and B.3 (app. B) clearly show this to be the case.

Careful consideration of these two tables, and also table B.4 (app. B), reveal distinctions between classes, as well as similarities. For example, permanent surface water occurred on 19, 46, and 100 percent of the intensive, multipurpose, and wildlife lands, respectively. In the same order, other than flat topography existed on 38, 48, and 50 percent of these land classes. Because both intensive and multipurpose lands are essentially agriculture, neither the number of vegetation types nor the number of fields differed significantly. Wildlife lands, in contrast, generally lacked vegetation diversity and had relatively fewer fields (or more aptly, "vegetation stands"), owing to the unmitigated effects of climate.

From a wildlife standpoint, each section of land interacts as a system with neighboring sections. The amount of "habitat" available on neighboring sections influences use of the central section by wildlife. From table B.2, intensive, multipurpose, and wildlife lands had 26, 54, and 100 percent, respectively, of their samples bordered by four or more sections with untilled land. Comparisons of untilled land within a sample site were, by definition, mutually exclusive for the intensively farmed and multipurpose classes. The reader may make analogous comparisons for the land classes listed in table B.3.

SPRING AND FALL PHEASANT DENSITIES

Densities by Land Use Type

Density estimates as used in this report are not intended as estimates of true population size. Rather, they are simply indicators of pheasant use with respect to land classes and certain habitat features.

Comparisons of pheasant density indicators with the intensity and type of land use revealed fairly consistent trends over the three years of study (table 3.1). Slight increases between 1976 and 1978 are believed to reflect a genuine improvement of populations throughout the Basin. This is corroborated by both cock crow counts (fig. 3.1) and harvest estimates (fig. 3.2). Portions of the East High may have been influenced by a gradual increase in crop diversity from the typical wheat monoculture. Some of the pheasant increases may have had a spillover effect on nearby unirrigated areas. However, field observations failed to establish a pattern of this nature; some remote sites similarly showed pheasant increases, while the converse was true on several sites adjoining irrigated farmlands.

Increases in pheasant abundance on some wildlife production lands (table 3.1) correlate with new farm units developing nearby. This was particularly evident in the Black Sands-Potholes Reservoir area wedged between Interstate Highway 90 and Frenchman Hills. Pheasant crow counts conducted by regional personnel of WDG (Washington Department of Game) have shown a dramatic up-turn in this area since call routes were begun in the early 1970's. Within the intensively farmed Columbia Basin Project, pheasant densities have also risen, but the influencing factors are not understood.

Comparing the data in table 3.1 by land use categories indicates no major shifts in pheasant abundance between categories from that shown by pretest data of 1976. This suggests that the classification scheme has, on a gross scale, reflected what managers have suspected all along; pheasant populations are indeed inversely related to the intensity of agricultural development, even though pheasants are generally benefactors of agriculture.

Those lands unirrigated, or only partially so, provide little of the habitat diversity associated with pheasant abundance. Untilled lands to the east of the Project are used primarily as livestock range. Only

Table 3.1.—*Estimates of pheasant densities per square mile during spring and fall for six land use classes in the Columbia Basin and Yakima Valley, Washington, 1976-1978 (n = number of square mile sections in sample)*

Land use category	1976 n	1976 Spring	1976 Fall	1977 n	1977 Spring	1977 Fall	1978 n	1978 Spring	1978 Fall
Intensive farming (B_1)	31	19	54	31	22	80	31	26	75
Multipurpose (B_2)	39	22	103	46	51	130	46	65	146
Wildlife production (B_3)	6	43[a]	63[a]	18	31	70	18	49	91
Untilled lands (A_1)	5	4	5	12	11	37	12	18	35
Dryland farming (A_2)	8	3	2	12	6	15	12	9	22
Private or incidental irrigation development (A_3)	6	0	27	9	10	33	9	12	36

[a] Values inflated by presence of large population of pheasants on one section. Deleting the atypical sample site yields mean densities of 18 and 39 pheasants per square mile during spring and fall, respectively.

infrequently do these lands show any variation in vegetal composition beyond the usual sagebrush-grass and grass-forb communities (cf. table B.3, app. B). Shrub cover is sparse as a result of fires on some of these rangelands. Overall, grazing is generally heavy with almost continuous close cropping of grasses and forbs. In a few cases, shrub and tree cover along drainages has been severely damaged by cattle and horses, thus lessening these extremely valuable cover types for pheasants, quail, cottontail rabbits, and many species of nongame wildlife.

Where soils and topography permit, dryland wheat long ago supplanted original native vegetation. Wheat provides abundant, year-round food for pheasants, and cover during summer, but offers nothing else. Farming for wheat leaves little room for perennial vegetation cover; vast, unbroken expanses of annually plowed land preclude the establishment of permanent cover. Stands of suitable cover occur in extremely low frequencies, most often along drainage courses and ponds or lakes. The majority of pheasant production and wintering use is restricted to wetland areas, particularly where wetlands and crops merge within the daily cruising radius of the birds.

Deep wells have tapped ground-water supplies in the East High. As a result, center-pivot irrigation is gradually replacing dryland cropping methods. Center pivots have been economically feasible for fields as small as 80 acres and up to nearly 360 acres. The most common size, however, is nearer a quarter section, or 160 acres. Center-pivot irrigated plots were at first viewed as a promising benefit for wildlife, since circle systems could effectively irrigate only about 78 percent of a quarter section. Thus, about 35 acres would be left untilled, eventually supporting permanent wildlife cover. On a square-mile section, this added up to approximately 140 acres of permanent cover. This irrigation would also break up the monotonous pattern of mile-upon-mile of uninterrupted wheat land. The consequent smaller fields and greater cropping alternatives would provide some of the diversity associated with good pheasant habitat.

Comparison of pheasant densities in A_2 and A_3 classes in table 3.1 suggests that this might have happened. Clearly though, private irrigation has not spurred pheasant populations to anywhere near that of the existing Columbia Basin Project. Even the most intensively used farmlands in the Project far outstrip East High irrigated lands in terms of pheasant abundance.

Such disappointing results are based on two factors. First, center pivots were soon developed with automated "corner catchers" or "sweepers" which eliminated the "wasted" ground in section corners. Second, sprinkler systems did not supersaturate soils to the point where wetlands formed in low areas. This is in contrast to the existing Project in which furrow-flooding techniques are the most common system. Wet areas greatly influence pheasant abundance by providing permanent cover plants on their margins (Baxter and Wolfe 1973 [4], Weigand and Janson 1976 [5], Foster and Myers 1979 [6]). Their absence from large areas of the East High thus posed a severe limitation on pheasant production.

Within the existing Project, multipurpose lands appeared to support more birds than either intensively farmed (B_1) or wildlife production lands (table 3.1). Yet the differences in densities were relatively small in view of the intensity of agricultural development. For intensively farmed sections, 97 percent of the land was in tillage. About 83 percent of the multipurpose class was farmed while only about 10 percent of the wildlife sites supported crops. With such differences in land use, one might expect wide divergences in pheasant abundance.

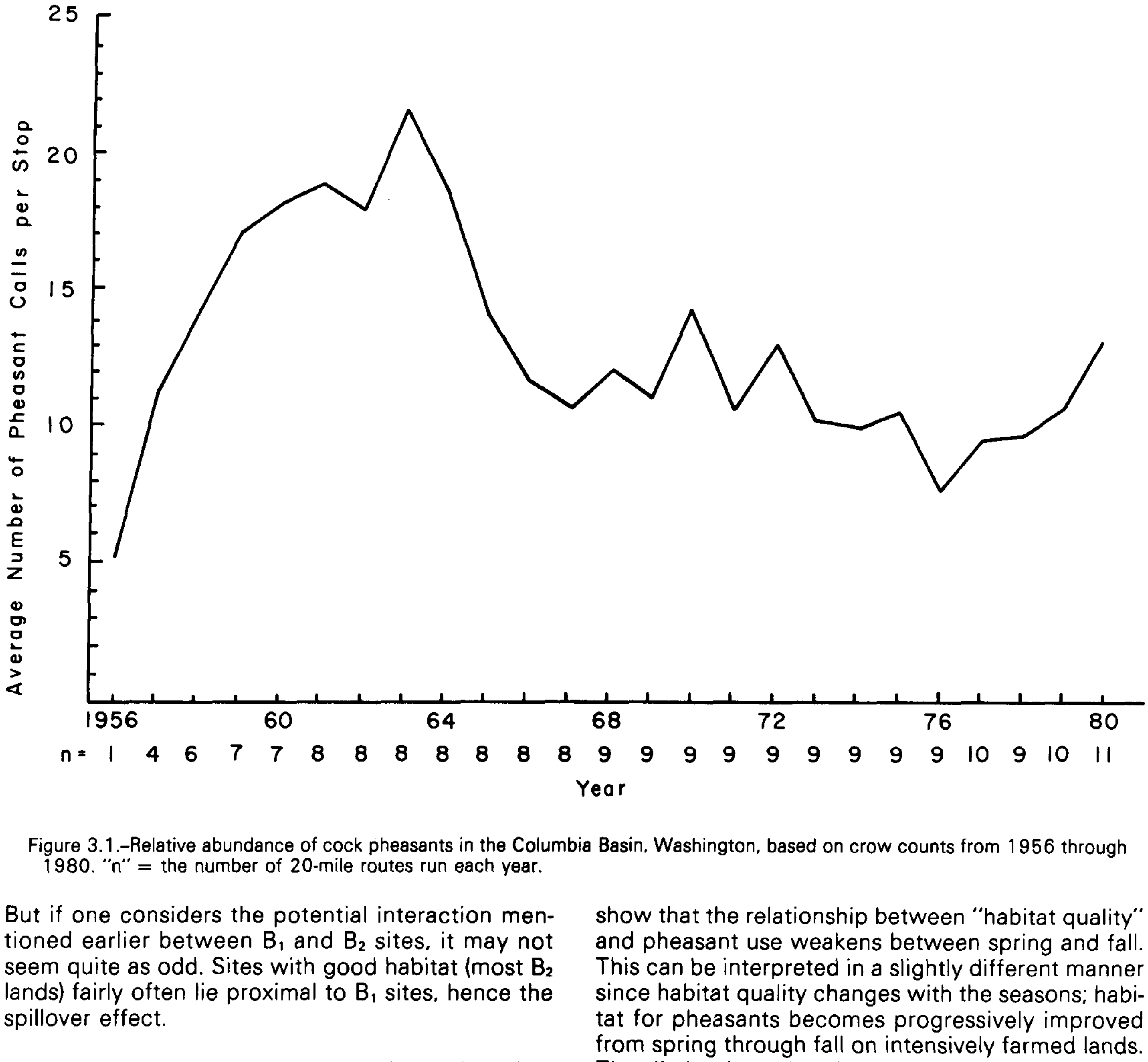

Figure 3.1.–Relative abundance of cock pheasants in the Columbia Basin, Washington, based on crow counts from 1956 through 1980. "n" = the number of 20-mile routes run each year.

But if one considers the potential interaction mentioned earlier between B_1 and B_2 sites, it may not seem quite as odd. Sites with good habitat (most B_2 lands) fairly often lie proximal to B_1 sites, hence the spillover effect.

Although vegetation cover is low during early spring, warming temperatures and reproductive urges stimulate dispersal from winter roosts. Pheasants, at this time, have less need of thermal cover and, until nesting begins, can get by in more marginal areas.

Late summer and fall surveys show a similar relationship in pheasant densities between land classes. Chicks have need of cover, but then cover is abundant in the form of mature crops on both land classes. They need not concentrate in the remnant patches of natural vegetation. Table 3.2 shows that differences in bird densities between B_2 and B_1 lands become proportionately smaller as the season progresses, a consequence of more abundant food and cover.

Regression analyses of densities and habitat index values further substantiate this. Figures 3.3 and 3.4 show that the relationship between "habitat quality" and pheasant use weakens between spring and fall. This can be interpreted in a slightly different manner since habitat quality changes with the seasons; habitat for pheasants becomes progressively improved from spring through fall on intensively farmed lands. The distinctions then between the good and poor habitat of spring are less evident by fall.

Wildlife production lands (B_2) fared better in 1977 and 1978, compared to 1976 estimates (table 3.1). At least part of the improvement is attributed to irrigation development near some wildlife areas. On the whole, pheasants on wildlife lands are impacted by remoteness from croplands (particularly small grains), overgrazing, and shortage of year-round food supplies. Insects (primarily grasshoppers) become fairly abundant in late summer of most years, thereby providing protein for growing chicks.

High variability in pheasant numbers occurred within and between wildlife sites during all years, but was highest during fall surveys. No birds were observed on 33 to 44 percent of these sites. Because of this variation, mean densities given in table 3.1 should

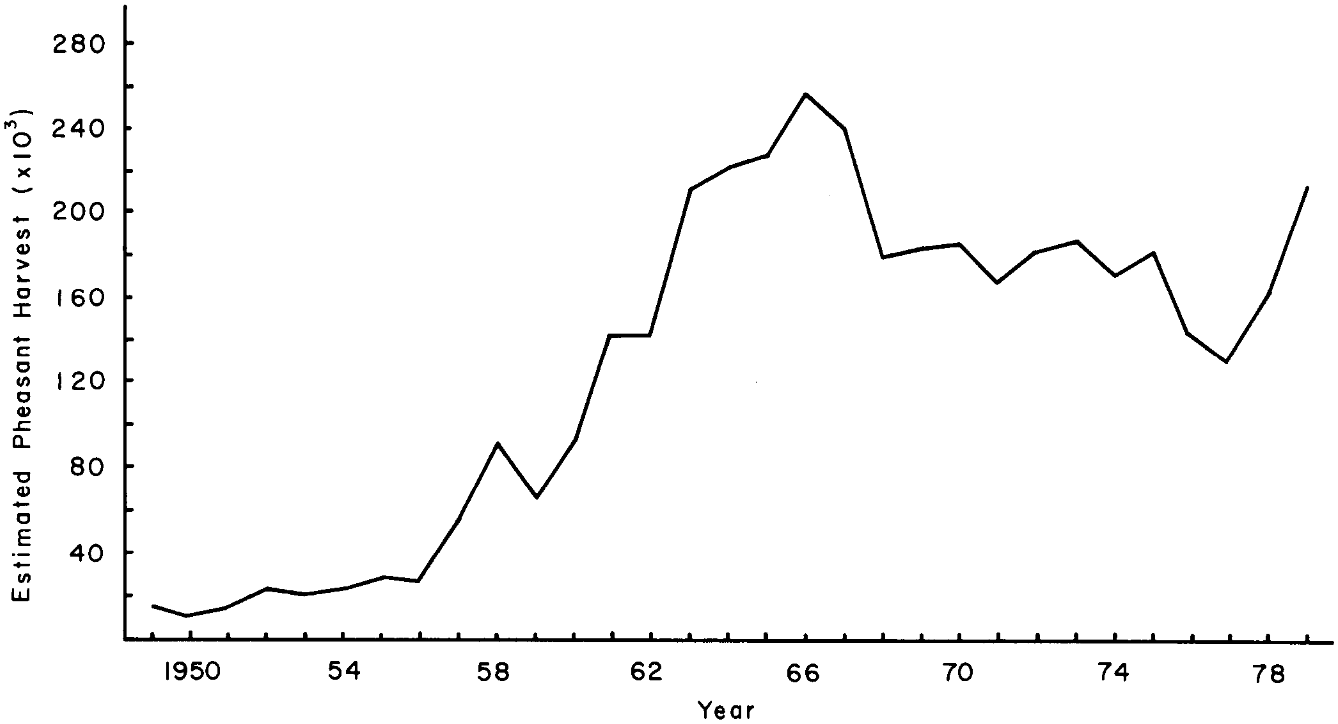

Figure 3.2.–Annual harvest of pheasants from Adams, Grant, and Franklin Counties, Washington, as estimated from hunter questionnaires.

be used with caution. Similarly, regression analyses failed to support a relationship with habitat index values as was evident for intensive and multipurpose lands (figs. 3.3 and 3.4).

Limiting Factors

In attempting to relate general spring and fall pheasant densities to habitat features in the Columbia Basin, several variables were examined. Quite a number failed to demonstrate any relationship to spring-fall densities. Thus, no specific increment of the summer population could be attributed to these conditions or features. On the other hand, certain features were useful indicators of reproductive performance (e.g., nesting, brood production) or were more important in describing winter habitat use, which ultimately affects the size of spring populations. These habitat features will be considered under the sections of "Nesting and Habitat" and "Winter Habitat."

The following discussion considers primarily habitat features, which were correlated with pheasant density. It also summarizes some features which bore no statistical support and suggests possible reasons for unrelatedness.

Soils

Soil mapping at the series level by the Soil Conservation Service had not been completed for Grant County by the end of this study. Attempts were made to compare, instead, large soil classes (i.e., soil associations) with wildlife densities. No relationships were found other than for lithosolic soils. This relationship was believed only superficial. The paucity of tall, dense vegetation is characteristic of lithosols and was more likely responsible for lack of birds.

The various arable soils were chemically treated to make up for natural deficiencies. Thus, the effects on pheasant densities were believed offset by chemical fertilizers such that distinctions were unnoticeable. Other land-use factors played a more significant role in wildlife densities.

Climate and Weather

Climatic conditions fall well within the ecologic amplitude of Columbia Basin pheasants. Although cooler temperatures and higher precipitation occur

Table 3.2.–*Relative differences in pheasant densities on intensively farmed (B_1) and multipurpose (B_2) lands between spring and fall*

Year	Comparison	Multiplier	
		Spring	Fall
1977	$B_2 > B_1$	2.4	1.6
1978	$B_2 > B_1$	2.5	1.9

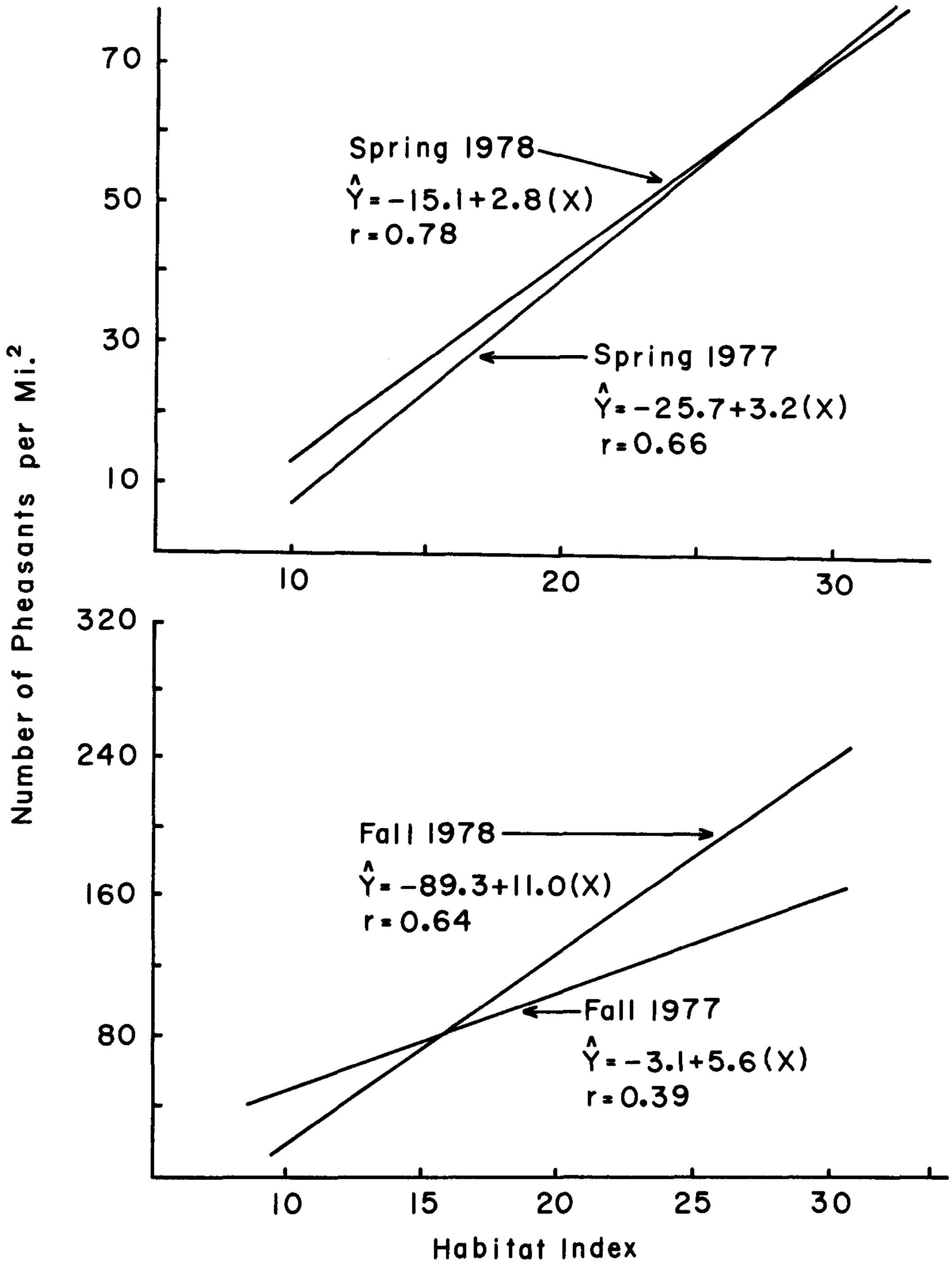

Figure 3.3.–Relationship between pheasant densities and habitat condition on 31 mi^2 of intensively farmed lands (B_1) during spring and fall, 1977-1978, in the Columbia Basin and Yakima Valley, Washington.

on a gradient from south to north in the Basin, the differences amount only to a few degrees and about 5 inches of annual precipitation.

Normal weather conditions prevailed during the spring-fall periods of this study; therefore, the effect of weather on densities remained uncertain.

Agricultural Chemicals

Various chemicals were used throughout the basin in preplanting soil treatments, weed and insect control in crops, and along waterways and roadsides to reduce herbaceous weeds. Their direct effect on pheasants was not examined in this study. However,

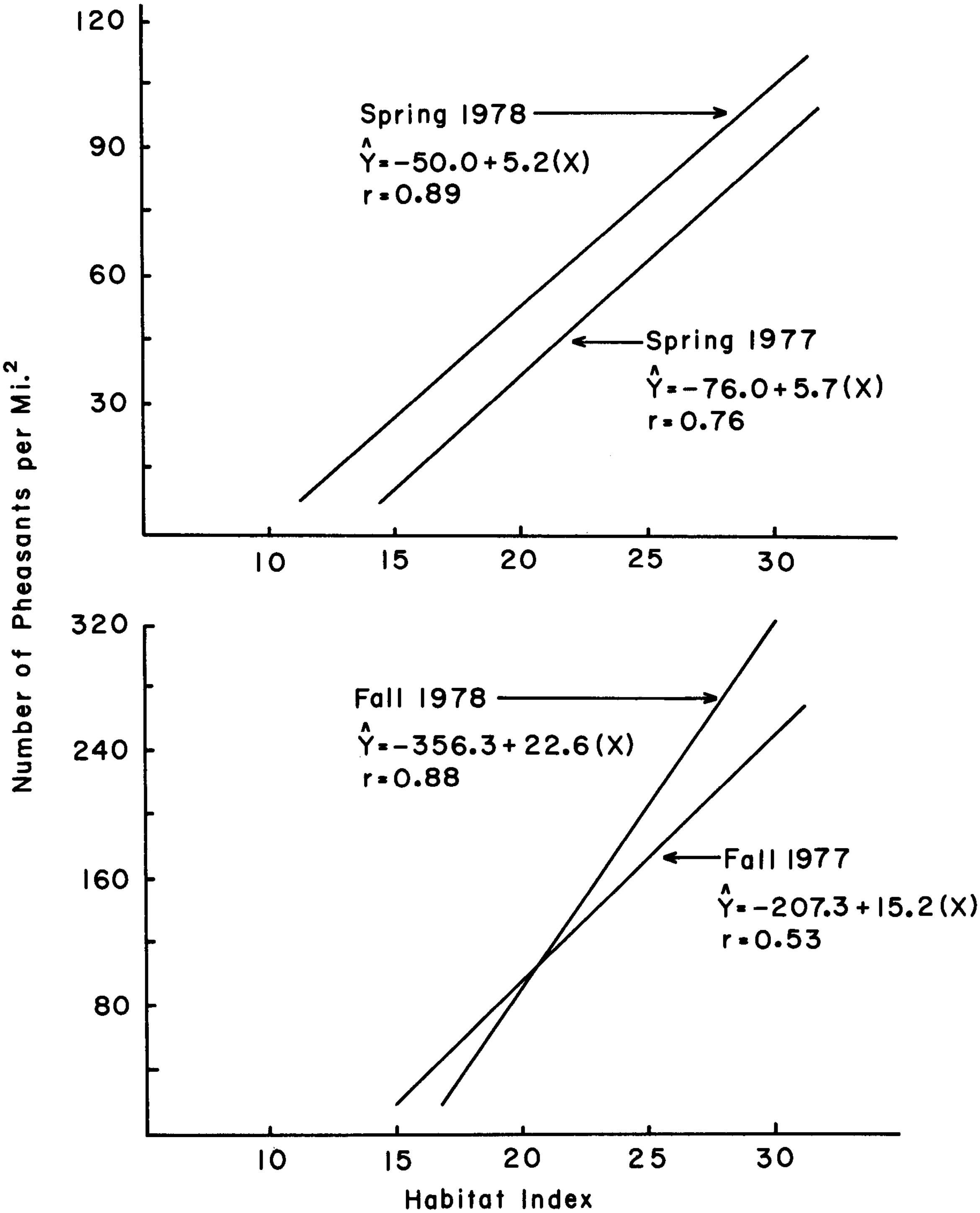

Figure 3.4.–Relationship between pheasant densities and habitat condition in 46 mi^2 of multipurpose lands (B_2) during spring and fall, 1977-1978, in the Columbia Basin and Yakima Valley, Washington.

in three situations, herbicide applications along canal banks and wetlands were followed by the deaths of two pheasant chicks, seven adult red-winged blackbirds, one yellow-headed blackbird, one killdeer, and two sparrows. Two days after a crop spraying near Warden, four abandoned red-winged blackbird nests were found in a small cattail patch bordering the field. One nest was empty; the other three contained dead nestlings.

Such observations provide only circumstantial evidence. Many other observations indicated no apparent losses of nestlings from chemicals. Yet the absence of carcasses from a sprayed area is also circumstantial. Unless field observations follow soon after chemical applications, the majority of carcasses may be lost to scavengers (Rosene and Lay 1963) [7].

Weed control chemicals chiefly affect pheasants and other wildlife indirectly by removing vegetation, which provides food and cover. These aspects will be discussed in later sections.

Irrigation System Design and Management

Open-channel delivery systems, as opposed to enclosed or buried systems, offer opportunity for vegetation development – an obvious benefit to wildlife. On intensively farmed sections in the Project, only 3 percent of the land area remains unused. Most of this is associated with the channel banks, spoil piles, borrow pits, and odd areas left in the wake of construction. Other than roadsides, open canal and drain rights-of-way represent the only alternative to noncrop nesting, but more importantly, as potential winter cover.

Vegetation cover along these waterways offers limited utility to wildlife during most of the year. Weed control efforts have reduced cover to short grasses, infrequent shrubs, or nothing at all. Excellent examples of well established, undisturbed cover do occur and form an important part of habitats.

Irrespective of farming intensity, 10 percent of the pheasants flushed during spring and fall surveys were on canal and drain rights-of-way. About 60 percent of these birds were flushed from the few areas with excellent stands of undisturbed vegetation.

The Columbia Basin Project was designed to irrigate crops by furrow flooding (or rill, gravity flow). Such a system entails an elaborate network of lateral canals, feeder or head ditches, and drain ditches varying in width of 2 to over 60 feet. In early Project days, these ditches and banks were not nearly so well manicured, nor was water delivery as efficiently controlled as at present. Ditchbanks sprouted dense grasses and forbs, and together with newly forming wet areas, pheasants enjoyed abundant cover. Since then, technologies have advanced the efficient use of water and land. Agrichemicals have stripped most of the head ditches and small laterals of vegetation. Concrete tile now lines many ditches and drains to reduce water loss. The width of ditches has been reduced so that more land can be farmed. Many landowners have done away with head ditches altogether; buried pipe in place of open ditches allows cleaner farming.

During early Project development, larger drain, lateral, and canal rights-of-way offered fairly frequent islands of quality cover. Small ditches functioned primarily as travel lanes between fields and the perennial cover of unused areas. This function is frequently overlooked in pheasant habitat needs. In a study of pheasants in the Texas Panhandle, Guthery *et al.* (1980) [8] identified this lack of strip vegetation for travel lanes as one of the most important factors limiting pheasants in that area.

Obviously, strip vegetation can be of only limited value in the absence of permanent areas of shrubby or woody cover or marsh vegetation. Such areas occur in the Basin, but at widely spaced intervals, or on Project peripheries. On intensively farmed lands, both the strip cover of roadsides and ditchbanks and the odd areas of woody or marsh plants occur in frequencies insufficient for pheasant needs throughout the year. Where 97 percent of the land is used, these represent the only areas left for habitat improvement.

On multipurpose lands, vegetation cover on ditchbanks has been subjected to the same treatments. What land managers fail to realize is that present methods of weed control are self-perpetuating. Control measures prevent natural succession and, hence, assure continued reinvasion by undesirable plants. Burning, spraying, and mechanical disturbance of ditchbanks and roadsides add costs to operations which exceed returns.

By comparison, rill systems produce more benefits to wildlife, on the whole, than do pressure systems, particularly center-pivot sprinklers. The latter permit large fields, unencumbered by delivery ditches and drains. With corner-catchers, these systems allow more complete use of a section. Water use has become highly efficient in that application rates can be tightly controlled. Sprinklers can be set to just meet the needs of the crop without supersaturating soils as is common in rill irrigation.

Physical Features

Tables B.2 and B.3 (app. B) show six features on study sections, which were tested for their contribution to wildlife densities. Two of these (number of fields and vegetation types) will be addressed later in the section entitled "Crops and Farming Patterns."

Because of considerable variation in pheasant numbers on wildlife (B_3), untilled (A_1), dryland (A_2), and privately irrigated lands (A_3), analyses and conclusions beyond those already given cannot be statistically supported. In this section, discussion is limited to intensively farmed (B_1) and multipurpose lands (B_2). These lands are of particular interest in that they better reflect potentials of new developments than do the other land classes. Since both B_1 and B_2 lands share similar physical characteristics, they have been pooled in the analysis.

Figure 3.5 reveals a fairly strong correlation between pheasant densities and the "condition" of habitat as expressed by four variables. Variables used in these regressions are: (1) type of surface water; (2) amount of topographic variation; (3) area of unused land present on a study section; and (4) the percent of adjoining sections which have 15 or more acres of unused land. For spring estimates, 86 percent of the variation is attributable to these four physical features. The relationship deteriorates some in fall, but still these habitat features account for 52 percent of the total variation. Results of fall data analysis tend to follow the thesis presented earlier regarding vegetation cover development. Cover cannot be considered a serious limitation to pheasant survival during late summer and fall under present land-use patterns.

Most of the private irrigation development of the East High and Black Sands areas operate by center-pivot systems. Correspondingly, pheasant populations are low. Less than half as many pheasants exist on large areas devoted to center pivots than on the highly intensified farmlands using primarily furrow flooding.

Analysis of the individual variables (physical or habitat features) indicated that spring pheasant densities varied directly and most closely with the amount of unfarmed land on a section (r = 0.83). Correlation with the other three features was, at best, weak; values of the correlation coefficient ranged from 0.47 to 0.51. Collectively, these three variables explained only 17 percent of the variation in spring densities.

The relationship between fall season densities and the four habitat variables was more diffuse; no one variable appeared to exert a significantly strong influence on total variation. Densities appeared to be slightly more correlated (r = 0.66) with water type, while r values ranged from 0.40 to 0.52 for other variables. The analysis suggests that perhaps all features are about equivalent in their relationship or influence on fall pheasant densities. With a combined effect of 52 percent, however, there are obviously other factors, which significantly influence fall densities.

Correlation analysis revealed virtually no relationship (colinearity) among the four physical features; thus, one variable did not appear to influence one or more of the others. These tests were considered in view of the potential relationships between topography and water type or topography and amount of unused land. The latter seemed highly probable, and in spite of poor statistical correlation on the study sites, may well be true if tested with different criteria. In general, however, one may find as much or more unused land on level sections as on the roughest terrain. Quite often, land is unused because of factors such as soil characteristics, drainability, proximity to water delivery systems, or lack of development capital.

Crops and Farming Patterns

Although the kinds of crops have changed very little since early Project development, farming methods have. Agrichemicals have largely replaced the crop sequencing and soil management practices used in early days to reduce pests and maintain soil productivity. Most early Project farms were characterized by small, irregularly shaped fields of diverse crops and rotational patterns. But as development continued, farming evolved into a highly capital-intensive endeavor. This transformation, as Wolfley *et al.* (1978) [9] pointed out, led to overcapitalized farming practices that required rapid return on investments. As a consequence, an increase in mechanization, crop specialization, and clean farming practices occurred. Average farm size rose from 100 to 320 acres; large farms became fairly common with acreages running upwards of 1,000 or more.

These increased cropping efficiencies adversely affected pheasants by reducing or altering favorable habitat characteristics. The objective of farmers was to produce a cash crop as efficiently as possible. But since pheasants had no price in the market system, the capital inputs (habitat development or protection) represented an irretrievable cost. Therefore, it was not in the best economic interest of landowners to produce wildlife if it meant committing valuable land to this end. Stated differently, destroying habitat was productive business.

Farmers did not purposely set out to destroy wildlife habitat; indeed, many lamented the decline of pheasants on their farms. Rather, farmers simply captured the opportunities to increase farming efficiencies. Pheasants, ever dependent on the level of crop production, were caught in the reallocation of crop-producing resources.

The new economics of farming did not allow inefficiencies which were permissible in the past. Lands had to be fully used, fields made larger, cropping more specialized, irrigation water more carefully metered, and crop pests more rigorously controlled.

These trends were visible during the course of the present study. Land-use classifications were in a state of flux as center-pivot systems were installed on previously unused lands or conversions made

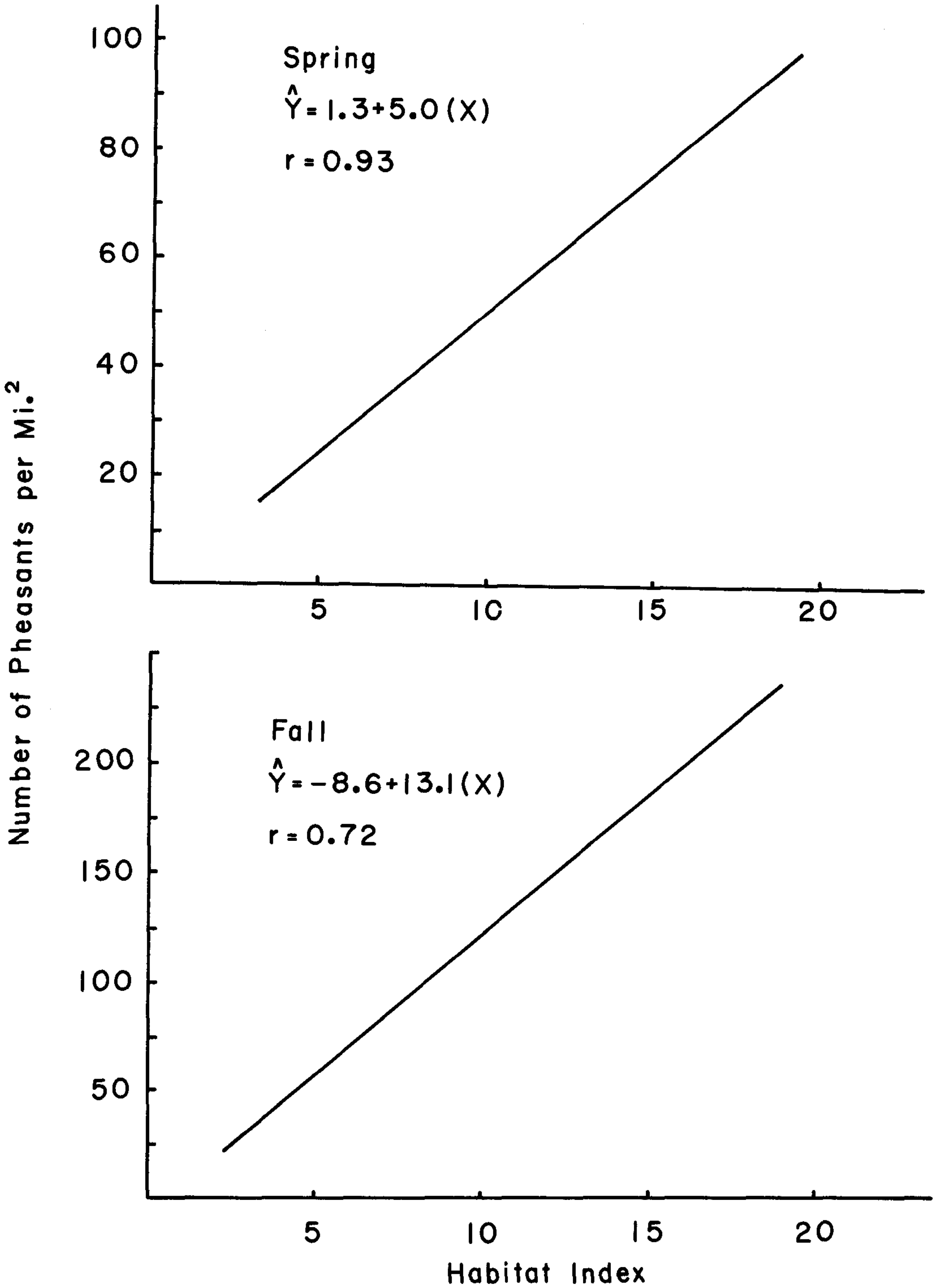

Figure 3.5.–Relationship between pheasant densities and habitat condition on 77 mi² of irrigated farmlands during spring and fall, 1978 in the Columbia Basin and Yakima Valley, Washington. (Pooled data for intensive and multipurpose lands).

from rill systems. Field sizes on some sites expanded at a rate of about 10 percent each year. A small sample of the B_1 and B_2 lands indicated an annual decline in unused lands (excluding rights-of-way) of about 4 percent between 1976 and 1978.

Larger fields bracketed the trend to specialized monocultures; it became more frequent to encounter whole sections within the existing Project devoted entirely to the production of alfalfa, wheat, beans, or potatoes. One-crop cultures were commonplace on newly broken ground.

Field sizes were not significantly different

($t_{0.05}$ = 0.18, 75 df) between B_1 and B_2 sites (means = 35 and 36 acres, respectively). Dryland farms were significantly greater ($t_{0.05}$ = 2.48, 19 df) in average field size (162 acres) than fields on privately irrigated farms (80 acres).

In comparing field sizes with pheasant densities, negative correlations would be expected between pheasant densities and mean field sizes for the major agricultural land-use classes (table 3.1). Pooled data for B_1 and B_2 lands, however, failed to show any such relationship (r = 0.12 and 0.20 for spring and fall pheasant densities, respectively). A slightly different test approach was tried; that is, the number of fields on a section became the independent variable. However, since mean field size is proportional to the number of fields, test results were essentially the same.

A second factor tested was vegetation diversity. The number of different crops and natural vegetation stands on a study section were examined with the dependent variables of spring and fall pheasant densities. Correlation coefficients indicated that vegetation diversity was unrelated to pheasant distribution and abundance during 1977 and 1978. Regression analysis of 1976 data suggested otherwise (r^2 = 0.62), but only weakly so. Standard deviations were high enough to shed doubt on the validity of dependency (Foster and Tillet 1977: 38-39) [10].

Attempts to compare pheasant densities with an interspersion index (Patton 1975) [11] fared no better. Thus, only the four variables mentioned earlier seemed to influence pheasant densities on irrigated farms in early spring and fall.

NESTING AND HABITAT

Nesting studies conducted during 1976-1979 investigated the importance of crops, unused areas, and rights-of-way for pheasant production.

The only crops of importance to nesting were those whose phenologies were early enough to offer dense nesting cover: winter wheat, alfalfa hay, barley, and mint. Other major crops such as potatoes, corn, and sugar beets fail to attract nesting birds until late June, well beyond the peak of the first hatch. Pheasants which use the latter crops do so mainly after failure of previous nesting attempts, and nest densities rarely attain levels significant to the population. Irrigated pasture is of little use to nesting pheasants in the Basin because of intensive grazing throughout the summer. Grass is seldom over 6 inches in height.

Considerable areas of right-of-way and other unused land occur in the Columbia Basin. The majority of unused areas tend to be concentrated in large blocks of several square miles. As such, their value to pheasants decreases with increasing distance from croplands. Those unused areas sprinkled amidst agricultural tracts are used extensively, provided that natural vegetation develops acceptable canopy coverage for nest concealment.

Nesting Densities and Vegetation Type

Nest searches were made on 2,528 acres of land between 1976 and 1978. Table 3.3 summarizes the findings. Active and hatched nests have been separated to indicate potential success or productivity for each vegetation type.

Overall, the data are believed to closely approximate actual nesting densities for each vegetation type, with exception of corn stubble. Three fields of corn residue were surveyed in the spring of 1978, the only year this was done. Nesting use of corn stubble was comparable to that found in natural vegetation types. The small amount of survey (3 percent of crop acreage) in this type, however, poses questions as to its representativeness. Since corn stubble seldom remains undisked as late as June, this type cannot be a significant contributor to pheasant production. And as with alfalfa cutting, pheasants run the similar risk of nest disruption should the farmer suddenly turn under the stubble.

Increased sampling of the natural vegetation types revealed generally small changes over what was reported during early studies (Foster and Tillett 1977) [10]. Nesting densities in the shrub/grass type were somewhat lower than expected from 1976 field work. Galbreath (1973) [12] reported nest densities ranged from 0.9 to 1.8 acres per nest in this type between 1970 and 1972. However, the number of shrub/grass sites in that study were considerably fewer than in the present work. The size of shrub/grass sites in 1976-1978 ranged from 0.2 to 25 acres and was distributed over the entire Project area.

Sample acreages were about evenly distributed between natural vegetation types (52 percent) and croplands (48 percent). Unused or idle areas, canal/drain banks, and roadsides made up 32, 32, and 36 percent, respectively, of the total area of natural vegetation sites. They included wide diversity in vegetation height and density. Because of this extensive (and intensive) survey effort, the estimates given in table 3.3 are thought to be reasonable approximations of nest densities over the entire Columbia Basin Project. They do not, however, reflect conditions on the large expanses of unbroken lands which border the Project. Areas such as Winchester-Frenchman Hills Wasteways, Columbia

Table 3.3.–*Summary of nesting densities of pheasants in various types of vegetation*[a] *in the Columbia Basin, Washington, 1976-1978*

Vegetation type	Acres sampled	Active and hatched nests	Acres/ nest	Total nests	Acres/ nest
Grass	126	4	32.2	15	8.4
Grass/forb	486	13	37.4	53	9.2
Shrub/grass	640	27	23.7	49	13.1
Willow/grass	55	10	5.5	14	3.9
Subtotals	1,307	54	24.2	131	10.0
Dryland wheat	136	1	136.0	1	136.0
Irrigated wheat	232	36	6.4	46	5.0
Alfalfa	772	178	4.3	231	3.3
Mint	41	4	10.2	4	10.2
Corn stubble	40	2	20.0	5	8.0
Subtotals	1,221	221	5.5	287	4.2
Totals	2,528	225	9.2	418	6.0

[a] Includes roadsides, canal and drain banks, and idle lands.

National Wildlife Refuge, Lower Crab Creek, and the rangelands bisected by Rocky Ford Creek can never support pheasant nesting on a par with Project lands, except where they merge with irrigated crops.

Crops were not sampled in proportion to acreage in the Project (table 3.4), mainly for reasons mentioned earlier. Irrigated pasture has been recognized by others as important to nesting pheasants (Baskett 1947 [13], Baxter and Wolfe 1972 [14]). This has never been true in the Columbia Basin, for cattle use has been so intensive that pastures rarely develop enough to conceal nesting birds.

Based on early studies in the Yakima Valley (O'Neil 1967) [15], mint production had generally risen and was believed to be of little value to pheasants. It was reasoned that mint might also increase in the Basin, and therefore, managers should have some idea of its value as nesting cover. At present, however, mint represents a small fraction of Basin production, and although pheasants nest in it, the crop contributes insignificantly to total nesting effort.

Nesting densities are highest in alfalfa and lowest in dryland wheat (table 3.3). The latter crop offers little cover because of low planting rates and natural precipitation. Alfalfa, with its early development and dense growth habit, is the preferred cover for early nesting. Galbreath (1973) [12] indicated that hen pheasants tend to renest in idle lands following disruption of nests during alfalfa harvests. Renesting attempts did not seem to favor idle lands in this study, based on surveys conducted during July and early August. Indeed, after the peak of egg hatch in mid-June, nesting on idle lands tapered off rapidly. Very few active nests were located on idle lands after the first day of July. At the same time, alfalfa and wheat fields maintained a relatively high density of nests (table 3.5). These data indicate that a considerable amount of renesting occurs in both alfalfa and wheat. Individual hens may select nest cover different from that of previous attempts; a hen disrupted by harvest of alfalfa may, in fact, move to another cover type. If this is true for the majority, then disrupted hens from other cover types subsequently use alfalfa in renesting. For the population, alfalfa appears to be the choice for renesting as well as for initial attempts.

Table 3.6 provides data on nesting success and failure and conjecture on production for each vegetation type. Overall, the minimum amount of nest failure for cropland nesters is 63 percent. This is derived by adding the totals of abandoned, deserted, and losses to alfalfa mowing. Because of losses in alfalfa, potential nesting success for all crops averages about 37 percent as compared to untilled lands with 43 percent success. These differences become relatively unimportant in view of the high frequency of nest destruction associated with untilled areas. Predation on eggs was associated with all destroyed nests. However, it is uncertain whether disruptions were predator initiated or if predators were involved after nests were abandoned.

Table 3.4.—*Principal crops grown in the Columbia Basin Project during 1976-1978*

Crop	1976 Acres (percent)[a]	1977 Acres (percent)[a]	1978 Acres (percent)[a]
Alfalfa, hay	133,525 (26.4)	162,948 (31.9)	154,108 (30.3)
Alfalfa, seed	9,620 (1.9)	11,898 (2.3)	13,205 (2.6)
Wheat	141,355 (28.0)	77,035 (15.1)	80,384 (15.8)
Sugar beets[b]	43,214 (8.5)	40,178 (7.9)	42,668 (8.4)
Potatoes	39,156 (7.8)	36,637 (7.2)	37,696 (7.4)
Corn, feed grain	28,732 (5.7)	46,961 (9.2)	34,275 (6.7)
Corn, sweet	8,379 (1.7)	12,420 (2.4)	13,595 (2.7)
Beans, dry	19,824 (3.9)	14,264 (2.8)	23,296 (4.6)
Irrigated pasture	18,154 (3.6)	17,476 (3.4)	17,259 (3.4)
Silage	13,345 (2.6)	16,060 (3.4)	10,860 (2.1)
Barley	6,098 (1.2)	14,647 (2.9)	16,794 (3.3)
Pea seed	8,452 (1.7)	11,195 (2.2)	15,026 (3.0)
Totals	469,854 (92.3)	461,719 (90.4)	459,166 (90.8)

[a] Percent of total irrigated acres.
[b] No longer a crop since closing of sugar refineries in 1980.

Table 3.5.—*Comparison of active pheasant nests on three cover types surveyed after July 1, 1976-1978*

Cover type	Acres sampled	Active nests	Hatched nests[a]	Acres per unhatched nest
Alfalfa	175	29	12	6.0
Wheat	101	12	12	8.4
Untillled lands	220	3	3	73.3

[a] Nests hatched prior to 1 July.

Assuming no further losses of active nests, the potential for success of nests in irrigated wheat surpasses that of alfalfa by nearly three times (potential production expressed as percent of total, table 3.6). Using acreage figures for 1978 (table 3.4) and nest densities from table 3.3, wheat fields yielded about 12,560 successful pheasants nests. Alfalfa hay fields, by comparison, produced 12,950 successful nests, even though alfalfa acreage is about twice that of irrigated winter wheat. Production for untilled lands cannot be estimated because total acres of this type are unknown.

Hen mortalities from alfalfa mowing amounted to 68.3 percent of hens on the nest at the time of swathing. Galbreath (1973) [12] and Foster and Tillett (1977) [10] reported mortalities as high as 89 percent. Compared to the total number of active nests (113) in alfalfa, 49.3 percent of the nesting hens were killed.

Two types of swathers are used to harvest alfalfa. The newer auger-type swather has been regarded as more lethal to incubating hens than the older, outdated swathers using a draper system. Testing of this hypothesis indicated that mortalities with draper swathers (64 percent) and auger swathers (69 percent) were not significantly different ($\chi^2 = 0.54$, $P < 0.05$).

Nest densities were compared for three irrigation systems. Center-pivot alfalfa fields supported a mean density of one nest per 4.7 acres; wheelline, or sideroll, sprinkler systems had one per 3.7 acres; and rill system fields contained a pheasant nest for each 2.5 acres. Chi-square analysis showed highly significant differences between center-pivot and sideroll ($\chi^2 = 64.2$, $P < 0.01$), and between sideroll and rill ($\chi^2 = 109.4$, $P < 0.01$). Reasons for these differences could not be related to field size because densities

Table 3.6.—*Nesting status and potential production for all pheasant nests by vegetation type found in the Columbia Basin, Washington, 1976-1978*

Vegetation type	Nest status[a] Abandoned	Destroyed	Active	Hatched	Potential production[b]
Grass	1 (17)	10 (67)	2 (13)	2 (13)	4 (26)
Grass/forb	16 (30)	22 (42)	5 (9)	10 (19)	15 (28)
Shrub/grass	3 (6)	19 (39)	15 (31)	12 (24)	27 (55)
Willow/grass	2 (4)	2 (4)	4 (29)	6 (43)	10 (71)
Subtotal	22 (17)	53 (40)	26 (20)	30 (23)	56 (43)
Alfalfa	38 (16)	15 (6)	113 (49)	65 (28)	65 (28)[c]
Irrigated wheat	8 (17)	2 (4)	14 (30)	22 (47)	36 (77)
Corn	3 (60)	0	1 (20)	1 (20)	2 (40)
Mint	0	0	1 (25)	3 (75)	4 (100)
Subtotal	49 (17)	17 (6)	129 (45)	91 (32)	107 (37)[c]

[a] Numbers in parentheses are percent of type total.
[b] Potential production is active nests + hatched nests, assuming no further destruction or abandonment.
[c] See text for derivation of figures.

were random in this respect. The intense and prolonged water application, characteristic of sprinkler systems, was thought to be detrimental to pheasant nesting. Desertion rates failed to support this; in fact, desertion was higher in rill-irrigated alfalfa (21 percent) than in fields with center-pivot and sideroll systems (both 15 percent). The best explanation appeared to be that rill irrigation fields, on the average, were more frequently associated with areas of winter cover. This was a vagary of sampling rather than a distinctness of rill-irrigated fields in general.

Nest placement with respect to field edge showed no correlation in this study. Nonrandom distributions were suggested by 1976 field work (Foster and Tillett 1977) [10]. Other investigators have also reported a distinct relationship between nest placement and edge (Musser 1962 [16], Wight 1945 [17]). Nevertheless, this general view of nest-edge relationship has proven invalid under closer scrutiny. Nelson *et al.* (1960) [18] pointed out that percentages of edge acreage compared to interior field acreage usually show a random pattern of nesting. Strode (1941) [19] observed a steady decrease in nest numbers from field edges toward the center. He explained that more nests seem to occur in the edge zone because this zone constitutes a large portion of the acreage of the field. In Colorado studies, Hoffman (1973) [20] concluded that nests were randomly distributed even though over 70 percent of all nests were within 15 feet of the nearest edge.

The use of strip cover (rights-of-way) and other idle lands averaged less than half that for croplands (table 3.3). Willow/grass type appeared to offer the best cover on unfarmed areas based on the small amount surveyed. On shrub/grass areas, a lack of dense understory grasses or forbs appeared the cause for low nesting use. Weed control and grazing were largely responsible, although soil characteristics also precluded much understory on some sites.

Table 3.7 summarizes results of rights-of-way use by pheasants. While nest densities have been high for this type in the Midwest (Linder *et al.* 1960 [21], Gates and Hale 1975 [22], Baskett 1947 [13]), it does not approach those densities in the Basin. Chick production from Basin sites adds little to summer production increments because of the high incidence of nest abandonment and predator disruption.

Rights-of-way comprised 72 percent of the untilled areas, yet contained only 48 percent of the total nests. Known nest failures were 65 percent, active nests 20 percent, and hatched nests 16 percent. Since predators were implicated in over half (56 percent) of nest failures on rights-of-way, the actual rate of failure may approach 75 percent of all nests.

Good cover on roadsides is somewhat of a rarity in the Columbia Basin. The potentially valuable strip cover they could support is repeatedly sprayed,

Table 3.7.—*Nesting densities of pheasants on various rights-of-way in the Columbia Basin, Washington, 1976-1978*

Type	No. miles surveyed	Total acres	No. of nests	Miles/nest	Acres/nest
Roadsides					
Federal	22	130	0	—	—
State	32	165	15	2.1	11.0
County					
Paved	47	138	21	2.2	6.6
Gravel	16	41	2	8.0	20.5
Subtotal	117	474	38	3.1	12.5
Waterway banks					
Main canals	20	94	2	10.0	47.0
Laterals	75	244	12	6.2	20.3
Drains	14	74	5	2.8	14.8
Subtotal	109	412	19	5.7	21.7
Roadsides/waterways	15	50	6	2.5	8.3
Totals	241	936	63	3.8	14.9

burned, disked, cropped, or used as frontage roads in moving farm machinery between fields. A few others serve as wastewater channels which require periodic dredging. Similarly treated are canal and drain banks.

Where pheasants attempt to nest on rights-of-way, they usually chose those rare plots of excellent cover. Pheasants also have been noted to nest on both rights-of-way and idle tracts with seemingly inferior cover. In this case, a single plant of residual Russian-thistle was most frequently selected.

The effect of strip width on nest site selection appeared inconsequential as nest numbers were evenly distributed among 11 width classes. However, analysis of the number of strips within each 5-foot increment class revealed that samples were skewed to the narrower widths; that is, down to widths of 10 to 15 feet. From 15 to 50 feet, the rate of decline in sample size for each class was rather constant. This suggests a nonrandom distribution of nest placement in favor of wider strips. No nests were found on rights-of-way less than 10 feet wide. Forty-one percent occurred on strips of 10 to 25 feet; 59 percent of the nests were in the range of 26 to 50 feet. The latter group of strips comprised only 33 percent of the total right-of-way samples.

Spring to Fall Habitat Use

The study of habitat use by pheasants requires tremendous expenditures of time and personnel, especially where the approach uses a time budget analysis. This technique examines an individual bird during allotted intervals each day, with time intervals varied daily until a full day is covered. The cycle is then repeated throughout the season. Data from such types of habitat use studies are generally without equal; the relative importance of each habitat feature is described by the time each bird spends in each situation.

Such in-depth analyses were beyond the scope of this study, objectively and practically. The methods used in this study can only be regarded as general indicators of habitat use. Point-in-time observations made during spring and fall density surveys form part of the basis for judging relative important of various vegetation covers to pheasants. They do not describe why a bird was in a given cover type, nor do they reflect the relative importance of the type to an individual pheasant. Nevertheless, a very large sample of point-in-time sightings becomes reliably descriptive for the population as a whole. Such an approach was used in this study and supplemented by more intensive data from radio-tagged birds.

The relative importance of various land types, and vegetation within these types, was estimated from observations of 2,230 pheasants. Table 3.8 shows seasonal distribution of observations for each land type. It comes as little surprise that croplands exceed other types, since crops occupy the majority of land in the Project. This is also consistent with the known affinity of pheasants for agricultural land.

Distribution between seasons within land types appears similar in table 3.8. "Goodness of fit" tests indicated differences were highly significant between spring and fall pheasant observations on croplands ($\chi^2 = 16.9, P < 0.01$) and for idle uplands ($\chi^2 = 38.1, P < 0.01$). Other land types appeared to maintain about the same importance to pheasants during both seasons. These results are consistent with the observations on pheasant densities presented earlier.

Wheat, alfalfa, irrigated pasture, corn, and wheat/corn stubble were the principal crops used during spring (table 3.9). Irrigated pastures were often the setting for crowing cocks and harems. Stubble was a prime feeding area, as were young corn fields. As fall approached, some shifts in crop use were apparent, yet extensive cover may have masked the relative use of some crops. Irrigated wheat had been reduced to stubble, much of which had either been burned or plowed under. Corn was used more, probably to a greater extent than indicated by table 3.9 in view of its high food value and protective cover. Beet fields offered excellent fall cover, as any pheasant nimrod can attest; the fields were virtually bare during spring. Other crops, except alfalfa and pasture, were used more in autumn by virtue of better cover quality.

Studies on radio-monitored hens have indicated that nesting and brooding hens have relatively small activity ranges. Hanson and Progulske (1973) [23], reporting on movements of 13 pheasant hens, found that home range sizes averaged 90 acres and ranged from a minimum of 16 to 182 acres. Hens monitored in the Columbia Basin during the present study averaged 74 acres (range 19 to 130) for seven hens near Quincy, Washington (Swedberg 1981) [3].

In view of these restricted home ranges, many of the cover types on a section of land may be unavailable to individual hens; yet for the population as a whole, the majority of cover types indeed become available and may be used, albeit a few types more so than others. Figure 3.6 shows the restricted home ranges of three hens and indicates the population effect on use of all cover types. Of nine hens monitored at the Quincy site, two had essentially the same activity centers (325 feet between their nests) during the monitoring period. Dispersal of other hens ranged to extremes of about 1.25 miles apart. Early spring counts on the central section (fig. 3.6) revealed a minimum of 50 hens. If dispersals of the nine tagged birds were indicative of the population, then it is logical to conclude most of the cover types would be available to the hen population.

The use of cover types by four radio-tagged hens on the Quincy study area prior to nesting generally

Table 3.8.—*Percentages of pheasants observed*[a] *in each land type during spring and fall surveys*

Land type	Spring	Fall
Croplands	51	58
Idle uplands	28	25
Wetlands	7	3
Roadsides	5	3
Drain bank	5	5
Canal bank	4	7

[a] 2,230 pheasant observations.

Table 3.9.—*Percentages of pheasants observed*[a] *in various types of vegetation during spring and fall surveys*

Land type/ vegetation	Spring	Fall
Cropland		
Wheat	14.0	7.1
Corn	6.7	17.5
Alfalfa	46.1	33.5
Beets	0.6	11.8
Potatoes	2.2	5.0
Asparagus	1.1	2.6
Mint	3.4	3.6
Beans	0.6	1.7
Peas	0.0	0.9
Irrigated pasture	7.3	5.5
Stubble	6.2	1.7
Fallow-harvested	3.9	6.8
Miscellaneous	7.9	2.3
Idle Uplands		
Grass	0.0	0.2
Forbs	32.3	46.1
Shrubs	63.5	46.1
Trees	2.1	6.8
Disturbed	2.1	0.9

[a] Observations made in wetlands and rights-of-way omitted. Percentages are based on total observations in each land type by season.

focused on wheat, row crops, strip cover, and corn in that order. During incubation (six hens), wheat again ranked high in use, followed successively by corn, wasteground (excluding strip cover), and row crops. Locations of nine brooding hens were most common in waste ground, wheat, alfalfa, strip cover, and corn. Waste ground was used more than any other type for brood rearing.

These observations should be regarded as generalities which are subject to the inherent errors associated with small sample size. If they are compared with observations in table 3.9, certain use characteristics appear to vary considerably. Most of this can be explained by the relative uniqueness of the Quincy study area; this area differs from the average conditions of agricultural lands. The 9-square-mile site, as described by Swedberg (1981) [3], is bisected by a central drainage containing excellent winter cover of marsh vegetation. This drainage way and adjacent uplands amount to over 300 acres and has a profound influence on pheasant numbers and their distributions. Strip cover along rights-of-way is abundant and generally of fair quality, especially within the central section (fig. 3.6). Abundant winter and strip cover are definitely atypical of the vast majority of Basin farmlands. Although alfalfa ranks highest in irrigated acreage of the Project as a whole, only 1.6 percent of the Quincy site supported this crop. Understandably, pheasants did not use it until later in the season of brood rearing.

Six pheasants outfitted with radios were also tracked near Warden during mid-April through June 1979. Locations made on hens away from their nests revealed that 30.5 percent of the cover types used were on unfarmed lands; strip cover (rights-of-way) comprised 10 percent of these pheasant locations. Alfalfa was much more prevalent at Warden than on the Quincy site and the majority of locations were in alfalfa (50.9 percent). Wheat stubble was being used in 11.9 percent of the locations, whereas row crops (3.3 percent), small grains (2.7 percent), and bare fields (1.3 percent) rounded out the cropland observations.

WINTER HABITAT

The type of vegetation cover and its quality, amount, management (or human use), and location in relation to croplands strongly influence the value of untilled lands as winter cover for pheasants. These factors account for dissimilarities in pheasant densities among various land uses in the Columbia Basin.

The winter of 1978-79 offered an excellent opportunity to assess the importance of various vegetative cover types for pheasant use. A cold snap set in during December 1978. Snow accumulated to 8- to 12-inch depths while temperatures plunged to 0 °F and below. A brisk wind, up to 25 miles per hour, further intensified the cold, which continued unabated well into February 1979, breaking the longest record for cold duration in central Washington (fig. 3.7).

Under such conditions, the importance of various vegetative cover types to pheasants is revealed. Table 3.10 suggests that intensive farming decreases value of winter cover to less than half that of lands under moderate uses. On the other hand, it appears that too much of a good thing may be even more debilitating. Wildlife lands, generally exhibiting abundant cover, seem to be the least useful as wintering areas. At least three considerations account for this anomaly; two implicate management decisions, the other is a matter of geography. A fourth factor may be design error, the effect of which was unmeasured. These effects will be discussed later.

Influence of Vegetation Cover

The incidence of undisturbed land greatly influences the capacity of an area to support pheasants. This was borne out by surveys conducted during an unusually cold winter, the results of which indicated the need for abundant, good quality cover in maintaining a healthy pheasant population. The basis of illustrating this lies in the classification of land use intensity as discussed in earlier sections of this report.

Intensively Farmed Lands

Roadsides and canal/drain banks formed the bulk of unfarmed lands on intensively farmed sections. These rights-of-way comprised 73 percent of the total sites sampled. Small, odd-shaped areas occurred infrequently.

Grasses or grasses and forbs predominated right-of-way sites; about 63 percent contained no woody plant species, or at most a few widely scattered individuals. Crested wheatgrass, foxtail, cheatgrass, and annual bluegrass were the most common grasses. A mix of forbs and grasses characterized most rights-of-way. Russian-thistle or tumble weed, mustards, knapweed, dock, lambsquarters, kochia, and scurf pea were some of the most conspicuous forbs. Floral variety was usually higher on roadsides than for waterway banks. About 33 percent of the rights-of-way supported sagebrush or rabbitbrush as the dominant overstory plants. The greatest variety and density of vegetation was found on idle lands; woody species occurred on 60 percent of the idle sites.

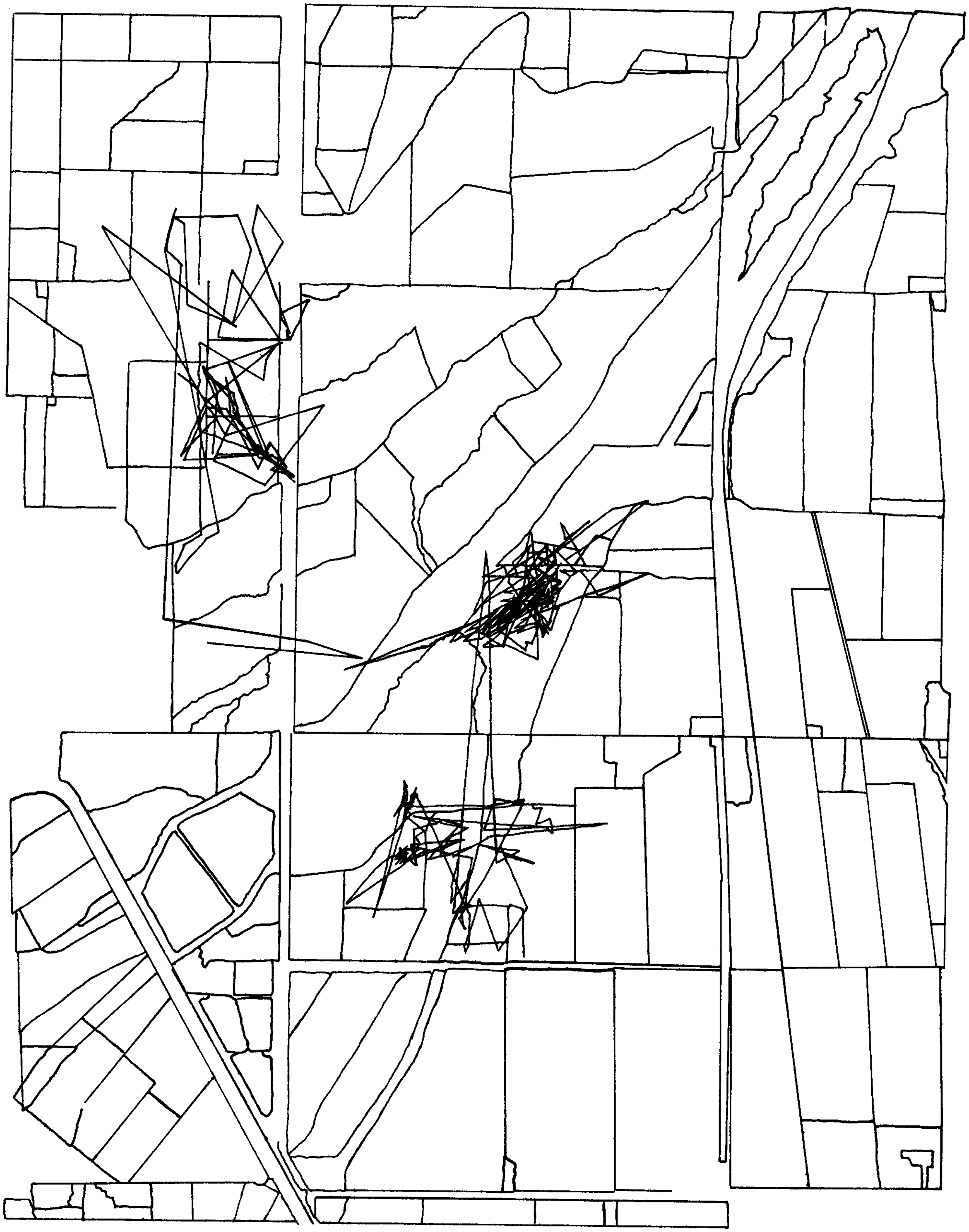

Figure 3.6.–Movements of three hen pheasants during the reproductive season on the Quincy study area in 1978. Map scale approximately 3 inches per mile.

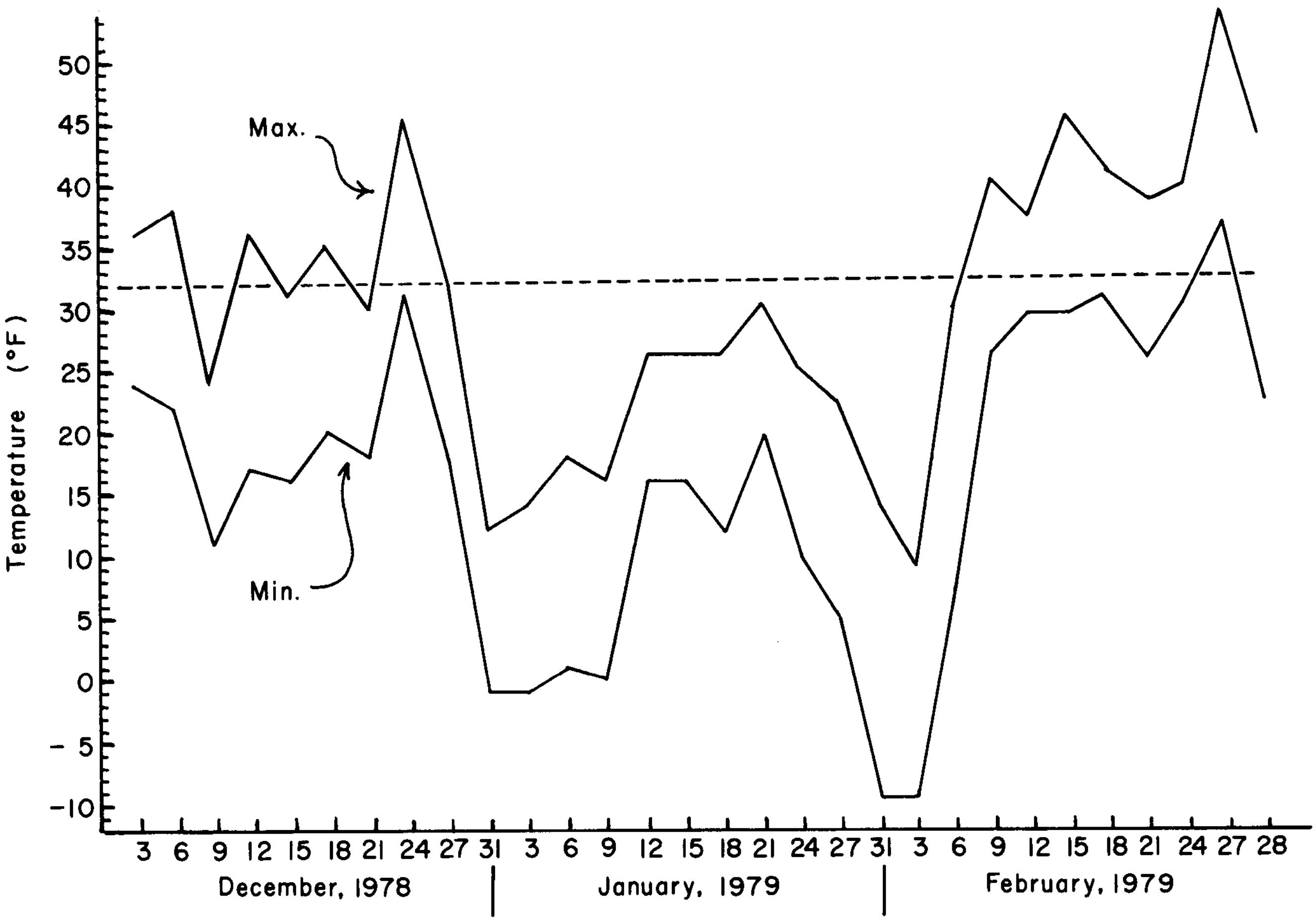

Figure 3.7.–Average maximum and minimum temperatures at Ephrata, Washington, during December 1978 through February 1979. Values represent 3-day averages except during the last 4 days of each month. Dashed line signifies freezing level.

Pheasants were found on only 13 (35 percent) of the sites on intensively farmed lands. The data in table 3.11 indicate that 97 percent of the pheasants were seen in areas supporting some form of woody vegetation in a dominant or codominant status. Herb and forb communities appeared useless for pheasants (0.05 bird per acre).

Multipurpose Lands

The number of sites were nearly equally distributed between idle and rights-of-way areas. Idle tracts were more frequent on this class than on the previous class, and comprised 83 percent of the total acres sampled on multipurpose lands. Acreage differences were a consequence of 11 sites which were greater than 20 acres in size. By definition, idle areas of this size would not be encountered on intensively farmed sections.

More rights-of-way with good cover and the bonus idle areas had profound effects on pheasant use of multipurpose lands; over 1,200 pheasants were counted (table 3.12). Study sites had an occupancy rate of 78 percent, in contrast to 35 percent for those of intensively farmed sections.

Data in table 3.12 show densities of 0.3 and 0.7 pheasants per acre in shrub and tree dominated cover types, respectively. However, willow/cattail types harbored 88 percent of the pheasants observed, with densities of 2.6 birds per acre. Willow copses, seldom taller than 12 to 15 feet, were usually dense and/or contained a profusion of tall forbs. Birds were found in 85 percent of willow stands, which was comparable to that of cattail patches (88 percent) and mixtures of the two (90 percent).

Wildlife Lands

Table 3.13 data reveal that wildlife lands supported 0.4 pheasant per acre. Essentially the same use patterns existed for vegetation on wildlife lands as on the other land classes. Shrub cover was believed to have been considerably more important to

Table 3.10.—*Comparison of pheasant counts on untilled areas in the Columbia Basin during the winter of 1978-1979 by land-use category*

Land-use category[a]	No. pheasants observed	No. acres surveyed	No. pheasants per acre
Farming	166	276	0.60
Multipurpose	1,245	799	1.56
Wildlife	77	210	0.37

[a] The "farming" category represents very intensive agricultural production. "Wildlife" lands are those managed exclusively for wildlife. "Multipurpose" lands include those that lack full agricultural development. Classification is based on land-use practices on 1 square mile.

Table 3.11.—*Number of pheasants, areas, and acreages in samples of various vegetation cover types on intensively farmed sites in the Columbia Basin, Washington, during December 1978—February 1979*

	Cover type					
	Grass	Grass/ forb	Shrub/ forb	Trees	Willow/[a] cattail	Totals
No. of pheasants	0	5	11	92	58	166
No. of areas	7	14	4	6	6	37
No. of acres	40	108	29	46	53	276
Pheasants/acre	0	0.05	0.38	2.00	1.10	0.60

[a] For brevity, areas containing willows or cattails or willows and cattails have been lumped into a single willow/ cattail cover type.

Table 3.12.—*Number of pheasants, areas, and acreages in samples of various vegetation cover types on multiple purpose lands in the Columbia Basin, Washington, during December 1978—February 1979*

	Cover type					
	Grass	Grass/ forb	Shrub/ forb	Trees	Willow/ cattail[a]	Totals
No. of pheasants	0	0	43	108	1,094	1,094
No. of areas	4	4	7	5	30	50
No. of acres	30	35	163	146	425	799
Pheasants/acre	0	0	0.26	0.74	2.57	1.56

[a] For brevity, areas containing willows or cattails or willows and cattails have been lumped into a single willow/ cattail cover type.

pheasants than is suggested by the data in table 3.13. The problem stems from the method used in categorizing vegetation on sites with a matrix of two or more cover types. Treating each type independently was impractical in the field because of small stand sizes which intermingled in a checkerboard fashion throughout the sample area. Where this problem arose, the cover type which recurred most frequently became the descriptor. At least one site with dense shrubs and several pheasants was, as a result, classified as willow/cattail.

Earlier it was mentioned that certain extraneous conditions probably account for the apparent low pheasant densities on wildlife lands, conditions which are completely unrelated to the quality of

Table 3.13.—*Number of pheasants, areas, and acreages in samples of various vegetation cover types on wildlife management lands in the Columbia Basin, Washington, during February 1979*

	Cover type					
	Grass	Grass/ forb	Shrub/ forb	Trees	Willow/ cattail[a]	Totals
No. of pheasants	–	0	0	25	52	77
No. of areas	–	1	2	1	3	7
No. of acres	–	11	77	43	79	210
Pheasants/acre	–	0	0	0.58	0.66	0.37

[a] For brevity, areas containing willows or cattails or willows and cattails have been lumped into a single willow/ cattail cover type.

vegetation cover. One of these conditions deals with location; some sites were distal to pheasant feeding areas (small grain fields). On 77 acres of wildlife lands located more than 0.5 mile from cropland, no pheasants were found. Where cropland was within 0.5 mile, 0.6 bird per acre was noted. Grazing by cattle appeared to negatively influence pheasant numbers also. Pheasants were absent from heavily grazed sites and occurred in densities of 0.4 per acre on lightly grazed sites and 0.7 on ungrazed areas. In making these comparisons, sites lacking nearby crops were excluded. Thus, the influence of grazing on pheasant use appears independent of cropland effects.

Management decisions regarding wildlife land may impinge on pheasants in the form of disturbance. As public lands, these areas represent perhaps the most intensively hunted pheasant range in the Basin. As a result, proportionately more of the population is harvested. Furthermore, intensive and recurrent hunting pressure tends to drive some birds off these lands while increasing the wariness of those remaining.

Wildlife lands were inadvertently the last category to be sampled. Surveys began in early February shortly after the cold spell broke (fig. 3.7). This may have introduced error to estimates of pheasant use. Pheasants generally begin to disperse as weather moderates, and thus may have emigrated from wildlife lands to marginal cover on adjacent lands.

The relative importance of various cover types examined on all land classes is summarized in table 3.14.

Parcel Size and Cover Quality

Data presented in the foregoing have amply demonstrated the relative value of various cover types to pheasants during winter. The next steps then are to consider optimum size of wintering sites and measures of cover quality.

In dealing with quality of cover, somewhat gross descriptions were used in this study. These descriptions have been defined in the footnote to table 3.15. Some subjectivity is inherent in these ratings; however, after viewing several sites under each quality rating, almost anyone could apply the system. Variations in rating between equally experienced persons would be minimal.

Table 3.15 reveals that 96 percent of all pheasants were observed on sites classed as having good cover. Both good- and medium-quality sites exhibited high variation in pheasant numbers, but this was not unexpected. More importantly, however, almost every site (92 percent) with good cover had pheasants. By comparison, birds were seen on 70 percent of the medium-quality sites, but only a scant 6 percent in poor-quality cover. Pheasant densities (from table 3.15) were 1.6 and 0.6 birds *per acre* in cover rated as good and medium. Sites with poor cover ratings, mostly low forbs and/or grasses, contained less than one bird *per 100 acres*.

Data failed to show any definite stepwise response in pheasant numbers between habitat size classes. In general, however, small areas seemed to exceed large areas in pheasant density. For good-quality cover, parcels up to 15 acres in size supported about 3.4 birds, whereas those parcels greater than 15 acres had densities of 1.0 bird per acre. Unusually high densities on areas up to 5 acres were biased by observations of 243 pheasants on 2 of 17 areas.

MANAGEMENT RECOMMENDATIONS

The principal factor affecting the pheasant population in the Columbia Basin is the lack of undisturbed summer and winter cover. Recommendations for enhancement planning therefore center on this need.

Rights-of-Way

Service roads along canals, laterals, and drains should be restricted to one side of the channel to

Table 3.14.—*Total number of pheasants, areas, and acres in samples of various vegetation cover types for all land-use classes (this table combines data from tables 3.2, 3.3, and 3.4)*

	Cover type					
	Grass	Grass/ forb	Shrub/ forb	Trees	Willow/ cattail[a]	Totals
No. of pheasants	0	5	54	225	1,204	1,488
No. of areas	11	19	13	12	39	94
No. of acres	70	154	269	235	557	1,285
Pheasants per acre	0.00	0.03	0.20	0.96	2.16	1.16

[a] For brevity, areas containing willows or cattails or willows and cattails have been lumped into a single willow/ cattail cover type.

Table 3.15.—*Pheasant numbers in relation to sample area size and quality of vegetation cover in the Columbia Basin, Washington, during December 1978—February 1979*

Sample area size class (acres)	Vegetation Cover Rating[a]					
	Good		Medium		Poor	
	No. of acres	No. of pheasants	No. of acres	No. of pheasants	No. of acres	No. of pheasants
0.1– 5.0	47.0	350	3.9	4	45.3	0
5.1–10.0	47.7	41	24.8	13	61.6	1
10.1–15.0	110.3	313	37.5	45	87.8	0
15.1–20.0	87.0	92	–	–	18.7	0
20.1–25.0	21.0	8	–	–	22.3	0
>25	587.0	620	45.0	0	38.1	1
Totals	900.0	1,424	111.2	62	273.8	2
Total no. of areas in sample	51		10		31	

[a] Good = dense growth, high species diversity, usually 2 feet or more in height. Medium = may have high number of different species in community, but low density or the converse, usually 2 feet or more in height. Poor = very sparse in density and/or species diversity low to monotypic, dominant plants nearly always less than 2 feet in height.

reduce disturbance to birds and provide more area for vegetation development.

Outside slopes of spoil banks and borrow pits should be seeded with mixtures of tall grasses, forbs, and native shrubs.

Topsoil additions and/or regular fertilizer applications may be necessary for plant growth on some parts of rights-of-way where subsoils low in nutrients have been exposed during construction.

Similarly, some areas should be provided irrigation water at least during the early period of plant establishment.

All habitat development plots must be protected from livestock, herbicide treatments, and fire. Burning of weeds should be restricted to inside slopes of watercourses, preferably within the area of maximum designed flow capacity. Herbicide applications should concentrate on target pest species and spot treatments as opposed to present canvassing methods. Fencing is recommended to protect outslope, borrow pit, and other rights-of-way areas from livestock grazing.

Many of the same recommendations made for irrigation watercourses are also applicable to roadsides.

Additional benefits for pheasants could be gained from cessation of mowing until 15 July. This would provide ample time for both pheasant and duck nesting to be completed.

Residual vegetation becomes a key element of nesting substrate for pheasant and ducks. Therefore, burning should be prohibited as well as tillage or use of roadside rights-of-way for interfield roads.

Farmlands

Wherever possible, wet areas which develop as a consequence of irrigation should be purchased in fee title or long-term agreements made with the landowner to maintain these areas for pheasants and other wildlife.

A minimum of 15 acres per square mile should be set aside for habitat development. Ideally, these set-aside lands should be divided into at least two tracts 0.25 to 0.5 mile apart. Desirable shrubs, forbs, and grasses should be planted, fertilized, and irrigated as necessary for establishment and maintenance. Tracts should be "squared up" rather than developed in long, narrow (less than 50-foot-wide) strips. They should be protected from grazing, fire, and herbicides.

Travel lanes should be created at no greater than 0.5-mile intervals. Probably the most ideal spacing would be at 0.25-mile intervals. Existing roadsides and watercourses could partly serve this function if good vegetation cover was maintained.

Such a distribution of habitat areas would not only increase numbers of pheasants, but provide a more even distribution throughout the irrigated area. Both nesting and thermal cover needs would be met by these areas. Dense cover on untilled areas would offer an acceptable alternative to nesting in alfalfa where high hen and chick mortalities presently occur.

Public Wildlife Lands

Eliminate grazing, especially where wildlife lands border cropland.

On large expanses of wildlife lands, small grains should be planted where croplands are greater than 0.5 mile distant. Several small tracts of up to 10 acres should be distributed over the area. Crop culture need only be minimal to provide winter food.

Wildlife managers should explore alternatives to reducing recreation activity on some wildlife lands during winter. Under present management, unlimited entry has become a highly disruptive influence on wintering wildlife and has literally driven birds into areas of inadequate thermal cover.

Water Rights

All habitat development areas must be granted rights to irrigation water for the life of the project. Without water, many areas will never develop sufficient cover vegetation or wildlife food crops to be of value.

Small wet areas that arise from seepage or wastewater collection should be purchased in fee title or acquired under long-term lease where they do not substantially interfere with farming operations.

SUMMARY

Land use, as measured by this study, has had a profound impact on pheasant populations. Of the six alternative uses, dryland wheat farming on the whole is least conducive to meeting the needs of pheasants. The typical scenario of dryland wheat country is one of mile-upon-mile of uninterrupted tillage, a checkerboard of bare, fallow soil and wheat. Roadsides are farmed nearly to the asphalt. Only rarely do islands of natural shrubs and grasses punctuate the monotony; it is these sparse oases which permit a few hardy birds to hang on through the winter.

Development of irrigation in lands east of the Columbia Basin Project has extended meager respite. Pheasants subsist at about twice the density of that of dryland farms, yet private water developments have not benefited wildlife any more than if the land had been left as rangeland. Crops are somewhat more diversified, but not much. Field sizes are still large and, more importantly, the tightly restricted water use of center-pivot systems virtually assures no wetlands forming at present levels of development.

Labor-intensive methods of farming characterized much of early-day Columbia Basin irrigated farms. Furrow flooding required a maze of delivery and drain systems and consumed landowner's time in operation and maintenance. With his hands full of normal farming activities, the landowner had little time left to clean up the odd areas or mow the weeds along field margins. Overapplication of water seeped through the soil mantle only to resurface at some other spot. Most of the early pheasant abundance is related to the inherencies of labor-intensive farming. To a considerable extent, many of these practices are continued today, but advances in technology have freed the landowner to clean up his farm and bring previously unused lands into production.

On the most intensively farmed sections of the Basin, 97 percent of the land is in crop production. Little cover remains for wildlife to use after crops have been harvested. About 83 percent of less intensively used lands support crops on the average. These sites, and neighboring wildlife management areas, furnish the vast majority of pheasants which radiate out into all lands during summer. Come winter when the protective crop cover is gone, clean farms become pheasant deserts.

Only four factors surfaced in this study which statistically correlated with spring and fall pheasant densities: (1) type of surface water, (2) topographic variation, (3) percent of adjoining sections with 15 or more acres of unused land, and (4) area of unused land present on a section. Spring densities were highly correlated with these four variables (86 percent). Most of the influence was attributable to the amount of unused lands on the study section. The relationship was less strong for fall pheasant densities, much as expected.

Spring correlations substantiate the dependency of birds on the vegetation cover offered by unused lands. During summer and late-fall, crops provide abundant cover and food; the birds need not rely on the idle tracts.

Cold weather and the snows of winter force pheasants to crowd into infrequent pockets of thermal cover, principally dense shrubs, willow patches, and cattail stands. Wherever these stands occur near croplands, they will definitely be used. Unfortunately, thermal cover has almost been abolished by clean farming practices. And on less thoroughly used farms, the trend points to fewer and fewer tracts of permanent cover.

The single most obvious factor relating to pheasant densities on all sites during winter was the abundance of good-quality cover. Pheasants were found almost invariably wherever woody plants dominated drier upland areas. The same was true where cattails occupied hydric soils. In general, the kind of site, whether roadside, canal and drain bank, or idle land, mattered little as far as pheasant use was concerned. If cattails or woody species were abundant, pheasants made use of the site.

Ditch banks and roadsides provide the least amount of protection to wintering birds. Yet these rights-of-way comprise over 70 percent of the unfarmed area on intensively farmed sections. They represent about the only areas left which could be managed for pheasant habitat without loss of farm crop production. Therefore, it is these rights-of-way strips on which judicious vegetation management offers the greatest potential for benefiting pheasants and other wildlife. Habitat development elsewhere on intensively farmed lands will likely be fleeting unless substantial economic incentives are guaranteed the landowner.

On less intensively farmed sections, a fair amount of untilled land remains. Large parcels almost invariably support cattle. Unless they include wetlands, natural vegetation cover may be quickly reduced to levels unsuitable for nesting birds. And as winter cover, grazed areas are only marginal at best.

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Chapter IV

WILDLIFE DAMAGE IN THE COLUMBIA BASIN

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WILDLIFE DAMAGE IN THE COLUMBIA BASIN

Irrigation development of the arid lands of central Washington caused wildlife to flourish, providing diverse opportunities for recreational use of the resource. Within the Columbia Basin Project, however, wildlife and associated recreational use have been met with mixed emotions. Hunters, fishermen and nonconsumptive users were elated over increases in wildlife abundance. The developing resource also stimulated local economies, providing an influx of "new money," jobs and additional tax revenues. But landowners, while deriving intrinsic pleasure from wildlife produced on their land (Seiter 1978) [1], often viewed the wildlife explosion in another light. Increased wildlife, to them, meant added costs to production of farm commodities. Furthermore, the attendent rise in recreationists placed additional social and economic pressures on landowners.

As a part of the Columbia Basin Wildlife/Irrigation Study, investigations were to address problems imposed on landowners and farmers by the wildlife resource. The objectives of this aspect were to:

1. Identify wildlife species involved;

2. Identify kinds of damage sustained by landowners;

3. Assess the extent of damage; and

4. Provide alternative recommendations for reducing or eliminating damages and losses to landowners.

METHODS

The area of concern was limited mainly to irrigated lands within Grant, Adams, and Franklin Counties. However, since existing records frequently cross these boundaries and may not always be identified as to area, the following discussions occasionally consider nonirrigated lands as well.

The approach to obtaining information was straightforward and simple. Informal interviews with farmers, irrigation district administrators, and field and staff personnel of the USBR (Bureau of Reclamation), FWS (U.S. Fish and Wildlife Service), and WDG (Washington Department of Game) revealed the wildlife species causing damage and the kinds of damages incurred. To assess the amount and frequency of damage, reliance was placed on records of complaints filed with WDG and FWS.

Because of the broad scope of work required in the overall Basin study and a lack of record keeping on damages by irrigators and landowners, no attempts were made to refine assessments beyond existing WDG and FWS records. Analyses of economic losses as a result of wildlife and recreationists were beyond the scope of this work. However, some crude dollar loss figures have been provided which serve only to indicate the potential magnitude of crop damage economics.

PERSPECTIVE

The presence of wildlife in the Columbia Basin has increased costs in the production of farm goods. These added costs originate from both direct and indirect influences on a variety of crops by wildlife. Direct influences are those in which wildlife consume or destroy the crop itself or cause indirect damage to production facilities, which in turn may either reduce crop yield or increase the cost of production. Examples of such damages could be muskrat burrowing in canal banks or plugging of drains and culverts by beaver.

Indirect damages may also occur to crop production by wildlife-oriented recreationists. Many landowners believe this to be more of a problem than wildlife itself. However, hunters, fishermen, or wildlife viewers may often be unjustly accused for the acts of vandals. This is not to say that recreationists are free of blame. When gates are left open permitting cattle to exit, vehicles driven through wheat fields to reach a fishing hole, errant shots pepper machinery or irrigation pipe, or wetland banks are littered by the refuse of fishermen, recreationists certainly increase the costs of the farmer to produce his crop. Added to this are the costs a farmer sustains in regulating recreational use of his land.

Wildlife on private land also imposes social costs which are widely recognized, although seldom documented. Rajala and Shew (1978) [2] examined the issue of social problems in considerable detail for the Columbia Basin Project. While social costs were not estimated by these investigators, their analysis suggests that these costs could greatly exceed those of direct damage to crops and production facilities. Thus, the influences of wildlife on farm production encompasses more than a simple loss of farm products. Neither social implications nor crop damages have been adequately analyzed to determine true costs of wildlife to the Basin's agricultural industry. Both are intertwined; to determine the costs of one without the other would present only an incomplete picture.

Wildlife related damages were a fact of life in the agricultural industry of the Basin long before irrigation was developed. Cattlemen perennially waged war with the coyote, and minor losses were incurred in dryland wheat from such species as waterfowl, rodents, rabbits, and badgers. The arrival of irrigation water permitted crop diversification and expanded wetlands. As a result, new habitats were created which attracted more waterfowl and increased resident populations of many other species. Crop losses were reportedly most severe during the 1960's when waterfowl and pheasant populations were at their peaks. Unfortunately, losses during this period were not well documented; losses sustained by agriculture were undoubtedly much greater than what the few meager records indicated. Recollections of 15 to 20 years ago tell us that many farmers were desperate in attempts to protect corn and wheat from a half-million or more wintering waterfowl. The advent of commercial drying of corn had not yet supplanted field drying which required that corn be left standing until December or January. Thus, the entire corn crop was vulnerable through most of the winter.

Crop damage by waterfowl gained the most notoriety. Little was mentioned in the records of other wildlife species from those early years. The FWS considered several management alternatives to reduce waterfowl depredation problems: allow hunting every day for geese instead of the present Saturday, Sunday, and Wednesday restrictions; open all areas of refuges to hunting; acquire new land and farm all available lands on existing management areas to provide feed for waterfowl; and liberalize bag limits on mallard and geese, the principal culprits in crop depredation by waterfowl (Cantrell 1964) [3]. Crop damage problems appeared so severe in the 1960's that Cantrell (1964) [3] expressed a wish to somehow divert the entire fall migration of waterfowl away from the Columbia Basin. Since then, changes in farm technologies and a decline in waterfowl numbers in the northern part of the Project have coupled to decrease crop losses. Even so, problems still persist, not only with waterfowl, but many other species as well.

Damages by all but a few wildlife species are so small or occur in such rare instances as to be negligible. Damage of economic importance varies temporally and may exert both direct and indirect effects on crops. For example, pheasants eat freshly planted corn kernels in the spring, imposing a direct impact on corn production costs. Later, when corn has started growing, a few farmers complain that dust bathing pheasants occasionally plug irrigation furrows, thereby depriving the crop of water.

Table 4.1 lists the principal species of concern to Columbia Basin agriculture and the most commonly associated damages. No order of importance is implied by the table.

AGENCY RESPONSIBILITIES

Wildlife management agencies have focused their attention on management and control of vertebrate wildlife, while invertebrate animals were left to the control ingenuity of agricultural agencies and industries. For wildlife agencies, this de facto allocation of responsibility for wild creatures is a blessing, for invertebrate animals represent the greatest economic threat to agriculture and are the most costly to control. Vertebrate wildlife, some protected by State and Federal laws and most by social attitudes, pose a different kind of threat for the landowner, one which he cannot as readily dispatch.

Federal regulations cover management and control of migratory birds and also rare and endangered species. The FWS is thus responsible for damage by this group of wildlife. All other vertebrates are usually handled by WDG in response to complaints. However, WDG is, by State law, responsible only for damages caused by big game animals (i.e., deer and elk). Where these damages occur, direct payments may be made after claims have been reviewed. Whenever big game problems are recurrent, protective measures are usually implemented in lieu of annual payments. The WDG has no legal responsibilities insofar as damages caused by other wildlife species. Yet, as a matter of internal policy, the agency has assumed responsibility for damages by species other than deer and elk. In essence, WDG has handled the vast majority of damage and nuisance problems as a gesture of goodwill.

Problems arising from rare and endangered species and migratory waterfowl come under the aegis of FWS. Most of the complaints in the Columbia Basin, however, are handled at the field level by WDG through interagency agreement. The FWS does not pay for damage caused by wildlife under its jurisdiction. Federal policy has been to provide materials, knowledge or physical assistance to the landowner or farmer to eliminate problems.

AGENCY CONTROL PROGRAMS

Ways of dealing with damaging and nuisance animals vary widely, as do the circumstances surrounding a grievance. Yet all measures of control can be more or less grouped under six basic methods: (1) destruction of animal, (2) relocation, (3) deterrence, (4) protection of property, (5) extension services, and (6) alternative food sources.

For game and fur-bearing animals, attempts are made to control animal numbers during recreational harvests. From agency and sportsmen's viewpoints,

Table 4.1.—*Summary of wildlife species and the type of damage they cause in the Columbia Basin, Washington*

Type of damage	Deer	Coyote	Badger	Weasel	Skunk	Beaver	Muskrat	Porcupine	Marmot	Small rodents	Rabbit	Geese	Ducks	Pheasant	Starling	Other
Predation on livestock		X														
Predation on domestic fowl		X		X	X											
Browsing orchards, ornamental trees and shrubs	X							X		X						
Plug culverts, drains, create flooding						X										
Burrowing in banks							X		X							
Prehavesting corn												X	X	X		X
Pre-harvesting wheat, barley												X	X	X		
Grazing alfalfa	X								X		X	X				
Grazing wheat	X								X			X				
Grazing pasture	X								X			X				
Eating planted corn seed, sprouts														X		
Girdling trees, shrubs						X		X		X	X					
Digging holes in crops and pasture		X	X						X	X						
Fouling stored grains, crops					X					X					X	X
General nuisance	X	X		X	X	X		X		X				X	X	X

this represents the most desirable alternative and has been very successful in preventing deer damage in the Basin. Although reduction through legal harvest is a most desirable means of control, problem areas arise which need more intensive attention. Generally, these situations can be corrected by reduction of one or a few animals. Shooting, kill-traps, and poisons comprise alternative methods of direct elimination of troublesome animals.

Except where reduction may be achieved through recreational harvest, agencies generally try to avoid killing troublesome animals for both aesthetic and safety reasons. A common practice in the Basin utilizes live traps. An individual animal may be trapped and relocated to an area where damage is unlikely to occur. Beaver, skunk, and porcupine are most frequently controlled in this manner.

Herding or hazing may occasionally force animals to relocate to less critical areas. Generally these techniques are applied to big game and waterfowl and are most appropriately termed as deterrent methods. Other deterrents include chemical repellents and a wide variety of visual and acoustical scare devices. Hazing provides only temporary relief, but buying a few days of time may be all that is necessary. Hazing is usually far less costly than destroying or relocating animals. As an example, newly planted corn becomes the target of pheasants during a critical 10-day period after planting. Scare devices can usually dispel pheasants from the corn for this period with a minimum of effort and cost, especially when automated devices are used.

Damages to crops and facilities can be prevented or stopped by employing protective devices such as fences, nets, and tree sleeves. Girdling represents the most frequent damage to orchard and ornamental trees and landscape shrubbery in the Columbia Basin. Damage by beaver, porcupine, small rodents, and occasionally rabbits represent the bulk of complaints in regard to trees and shrubs. Plastic sleeves or wire wrapped around tree trunks are effective protection from these offenders.

A high number of animal problems are dealt with indirectly through extension services. Both WDG and FWS participate in giving advice on how to prevent or reduce losses to individual complainants. They often go a step further and provide materials and equipment. At times, the bulk of extension services are devoted to coordination of landowners (mainly livestock growers) and private trappers and varmint hunters. Landowners with a history of problems are contacted and provided the names and addresses of screened trappers and hunters. The program has remained relatively small but appears to have been quite successful on its present scale.

County agricultural extension offices frequently pass on information obtained from wildlife agencies to aid in control of nuisance animals. Extension services form an important part of the methods of relieving damage problems throughout the Basin. This program has special value during critical periods when agency personnel are spread thin.

Perhaps one of the most costly control methods is that of providing alternative food sources. Some public lands have been dedicated to producing wildlife food as a means of reducing wildlife consumption of farm crops. The amount of land needed to eliminate private crop losses, however, far surpasses that presently under public ownership. And too, most public land controlled by wildlife agencies in the Basin has marginal value, or no value at all, for crop production. New acquisitions of arable land to produce wildlife food have been resisted for several reasons. Initial purchase prices, subsequent development costs, and operation and maintenance costs are high and thus have dampened enthusiasm. In addition, the prevailing attitudes among irrigation interests have been against converting commercial farmland to wildlife uses. Although the potential for decreasing at least waterfowl damage to crops could be high, current economic and social constraints have largely ruled out alternative food sources in the Project area.

CROP LOSSES AND POTENTIAL COSTS

Records on crop losses and other damages appear sketchy at best. Table 4.2 summarizes damage and nuisance complaints in the Columbia Basin during recent years. These data represent the total number of complaints on file at WDG's Ephrata office, and also additional waterfowl complaints provided by the Columbia National Wildlife Refuge. Table 4.2 shows 374 complaints were recorded during the 7 years of 1974-1980, an average of about 53 per year. For irrigated lands, the average number of complaints is less since some of the records come from outlying, unirrigated areas.

In view of the frequent and strong concerns voiced by public and private groups, it is particularly interesting that so few complaints appear in the records. Irrigation interests have continually alluded to widespread, nearly incessant and devastating damages suffered by farmers as a result of wildlife in the Project area. Public agencies readily agree that wildlife damages are indeed a serious problem, yet the number of complaints suggests otherwise. This discrepancy is deferred to a later section dealing with problems on assessment of damage and related statistics.

Table 4.2.—*Summary of wildlife damage complaints and control measures taken, by year and county, in the Columbia Basin, Washington, 1974-1980 (information in this table is not restricted to Columbia Basin Project area)*

Year	County	Wildlife species	No. of complaints	Type of damage	Corrective action
1974	Grant	Deer	2	Shrubs	Hazing
		Elk	1	Wheat	Hazing
		Weasel	1	Nuisance	Live-trap
		Beaver	7	Trees, plug culverts	Live-trap, wired trees, trap, shoot
		Marmot	1	Wheat burrowing	Fumigant, plug dens
		Muskrat	1	Dike burrowing	Advise trapping
		Waterfowl	3	Corn, wheat	Hazing
		Sparrows	1	Wheat	Hazing
	Adams	Beaver	1	Plug culvert	Live-trap
1975	Grant	Skunk	1	Nuisance	Repellant
		Coyote	1	Sheep	Unknown
		Beaver	2	Trees, flooding	Traps
		Geese	1	Wheat	Hazing
		Ducks	1	Corn	Hazing
		Pheasant	1	Haystack	Hazing
	Adams	Dogs	1	Sheep	Unkown
		Coyote	3	Sheep, cattle, nuisance	Unknown
		Beaver	1	Flooding	Traps
		Ducks	1	Corn	Hazing
	Franklin	Coyote	1	Watermelon	None
1976	Grant	Deer	3	Apple trees	Repellnt, herding
		Weasel (rats?)	1	Turkeys	Advise traps, poison
		Badger	1	Digging in wheat	Traps
		Skunk	5	Nuisance, garden	Live-trap, repellant
		Raccoon	1	Corn	Traps
		Coyote	10	Turkeys, ducks, sheep, cattle, house cat, digging in wheat	Traps, shooting, advice
		Beaver	22	Shade trees, dams	Traps, wire trees, live-trap, advice
		Porcupine	3	Girdling trees	Live-trap
		Marmot	1	Wheat	Traps
		Muskrat	1	Burrowing banks	Advise traps
		Geese	2	Wheat, pasture	Hazing, advice
		Pheasant	6	Corn, beans, water-melons, garden	Hazing
	Adams	Dogs	1	Sheep	Traps
		Coyote	23	Nuisance, sheep, cattle	Traps
		Pheasant	2	Corn	Hazing
	Franklin	Coyote	16	Cattle, sheep, nuisance, chickens, watermelons, chew irrigation hose	Traps, shooting, denning, advice
		Beaver	1	Trees	Wire trees
		Muskrat	1	Burrowing dikes	Provide traps
		Pheasant	3	Corn, wheat	Hazing
1977	Grant	Deer	2	Unknown	Hazing
		Badger	1	Digging in wheat	None

Table 4.2.—*Summary of wildlife damage complaints and control measures taken, by year and county, in the Columbia Basin, Washington, 1974-1980 (information in this table is not restricted to Columbia Basin Project area)*—Continued

Year	County	Wildlife species	No. of complaints	Type of damage	Corrective action
1977	Grant	Skunk	5	Nuisance	Traps
		Raccoon	1	Fruit	Traps
		Coyote	16	Sheep, cattle, nuisance	Traps, shooting
		Beaver	10	Orchard trees, flooding	Wire trees, traps, live-trap
		Muskrat	2	Burrowing in banks, dikes	Traps
		Marmot	1	Wheat	Traps
		Porcupine	2	Girdling trees	Live-trap
		Rabbit	1	Unknown	Unknown
		Geese	9	Wheat, pasture	Hazing
		Ducks	4	Corn	Hazing
		Pheasant	4	Corn	Hazing
	Adams	Badger	2	Digging, nuisance	None
		Skunk	4	Nuisance, chickens	Traps
		Coyote	21	Sheep, cattle, nuisance	Traps, denning, shooting
		Beaver	5	Flooding, trees	Live-trap, wire trees
		Marmot	2	Unknown	Unknown
		Porcupine	1	Unknown	Unknown
		Geese	2	Wheat	Hazing
		Pheasant	23	Corn, rill ditches	Hazing
		Hawk	1	Unknown	Unknown
		Sparrow	1	Unknown	Unknown
	Franklin	Coyote	1	Cattle	Advice
		Beaver	2	Plug culverts	Live-trap
1978	Grant	Coyote	12	Cattle, sheep, digging in wheat	Traps, shooting, poison
		Geese	7	Wheat, alfalfa	Hazing
		Ducks	5	Corn	Hazing
		Starlings	2	Sunflowers, cherries	Hazing
	Adams	Coyote	5	Sheep	Traps
		Ducks	2	Corn	Hazing
		Other birds	1	Unknown	Unknown
	Franklin	Coyote	14	Sheep, cattle	Traps
		Beaver	3	Flooding	Traps
		Magpies	1	Unknown	Unknown
1979	Grant	Coyote	7	Sheep, cattle, turkeys	Traps, denning, poison
		Geese	2	Wheat	Hazing
		Ducks	2	Corn	Hazing
	Adams	Coyote	9	Sheep, cattle	Traps, shooting, denning
		Skunk	2	Alkali bees	Traps, hazing
		Geese	2	Wheat	Hazing
		Pheasant	2	Alkali bees	Hazing
	Franklin	Coyote	1	Sheep	Traps
		Geese	1	Wheat	Hazing
		Ducks	2	Corn	Hazing
1980	Grant	Coyote	3	Sheep	Traps

Table 4.2.–*Summary of wildlife damage complaints and control measures taken, by year and county, in the Columbia Basin, Washington, 1974-1980 (information in this table is not restricted to Columbia Basin Project area)*–Continued

Year	County	Wildlife species	No. of complaints	Type of damage	Corrective action
1980	Grant	Beaver	3	Trees	Live-trap, wire trees
		Skunk	2	Unknown	Unknown
		Rabbit	1	Unknown	Unknown
		Porcupine	2	Unknown	Unknown
		Geese	10	Wheat, alfalfa, pasture	Hazing
		Ducks	2	Corn	Hazing
	Adams	Coyote	5	Cattle, sheep	Traps, poison
		Beaver	1	Unknown	Unknown
		Geese	1	Peas	Hazing
		Ducks	1	Wheat	Hazing
	Franklin	Coyote	1	Unknown	Unknown
		Weasel	1	Unknown	Unknown
		Skunk	1	Unknown	Unknown
		Geese	1	Wheat	Unknown

Coyotes, beaver, pheasants, geese, ducks, and skunks, in about that order, appear to be the principal source of complaints based on the data in table 4.2. These six species accounted for 88 percent of the complaints. Coyotes were the single biggest concern; they numbered 40 percent of the complaints. Most of the reported damage by coyotes was for loss of ewes, lambs, and calves during late winter through early spring. Occasional losses were reported for domestic fowl and house pets and every so often adult coyotes are accused of digging holes in canal banks and wheat fields. At least one report was for damage to plastic irrigation lines – chewed on by coyote pups.

Coyote complaints arise from all over the Basin, but the majority come from livestock ranges in dryland areas. Within the Project, coyote problems are relatively few.

Coyote predation on livestock has been effectively reduced by removal of the coyote. Annual control programs on livestock ranges, especially before grazing starts, has been and continues to be the most beneficial and productive approach to reducing predation. Changes in farming practices such as shed lambing, clean up of dead carcasses, and adjustments in the timing of grazing can be used to reduce losses. However, experience has shown that convincing some growers that predation losses can be reduced by simply changing a few established practices has been difficult.

With the rise in demand for coyote on the fur market, some farmers have come to regard coyotes as a marketable resource. Thus, during the last few years, some landowners have been selling trapping and hunting rights to the highest bidder. Yet, during the remainder of the year when coyote pelts are poor in quality, these same landowners expect to receive public assistance for coyote reduction.

Problems arising from beaver in the Project amounted to 16 percent of the complaints listed in table 4.2. Very likely beaver complaints may even surpass those of coyotes within irrigated farmlands. Damage by beaver stems from their two most notorious traits: building dams and gnawing on trees. Wherever land use is intensive, both of these activities pose economic as well as nuisance threats. Dams cause flooding of nearby crops, roads, or pasture and may induce severe erosion on occasion. In more remote areas of the Project, cutting trees by beaver may be of little consequence. It is when the animal moves into orchards or chews on ornamental trees and shrubs that landowners become disquieted.

Together, ducks and geese contributed to 16 percent of wildlife damage claims. In irrigated lands, ducks were the primary cause of complaints, and this caused exclusively by mallards. Considered almost a plague by many farmers in the 1960's, mallards continue to be resented for their free loading in cornfields and feed lots over parts of the Basin. Recent shifts in mallard wintering areas, along with early corn harvests, has lessened the frequency of corn losses in the Basin. A considerable amount of complaints arise from farmers who utilize corn crops for wintering their cattle. Ducks generally avoid fields that are being grazed, except when fields are blanketed by snow. If undisturbed, mallards can strip a field of corn before cattle are turned in to graze.

Goose damage usually occurs in early spring and centers on young winter wheat plants, and to a lesser extent on alfalfa. Most damage claims on geese occur in the vicinities of water fowl refuges – mainly the Stratford and Columbia National Refuge areas.

In some alfalfa fields, estimates have ranged as high as 80 percent loss of the first cutting. Fortunately, alfalfa losses represent only a small fraction of total Basin production. Studies conducted on goose damage to wheat have shown that most complaints come from dryland farms and are comprised of two modes of damage. Both of these take place only under certain soil moisture conditions. If the field is wet or flooded, large numbers of geese may compact the soil as they walk about. When "paddling," as it has been termed, occurs, wheat growth may be eliminated in the area of compaction.[1] The second mode of damage is extraction of the entire young plant from the soil. Interestingly, studies of so-called damage areas reveal very little or no loss at all of wheat production even though several thousand geese may have foraged there. In fact, some test plots suggest possibly greater production occurred where geese grazed than where they were absent[1]. In most cases, the anxiety associated with goose grazing appears to outweigh actual damage.

Even so, WDG and FWS have attempted to resolve all conflicts inasmuch as their resources allow. Hazing and herding have been standard methods used over the years, but admittedly offer only short-term relief to the farmer. Since most wheat damage occurs in early spring, both farmers and wildlife personnel rest easier after geese have migrated out of the area.

Pheasant problems remain fairly high on the list of complaints (11 percent). Damage by these birds is limited mainly to corn as has been previously discussed. Pheasants and corn are both widely distributed throughout the Project; reported damages to corn naturally follow suit. Fortunately, the critical period of losses is short-lived and hazing techniques generally satisfy their objective once implemented. Yet considerable losses of seeded kernels or sprouts may have already occurred by the time pheasant control operations begin.

[1] D. Gälbreath, personal communication.

Undoubtedly pheasants forage on corn throughout the growing season. These losses by pheasants do not seem to raise the ire of landowners as do those by waterfowl. With pheasants, the farmer deals with but a handful of birds; but waterfowl may number in the thousands on a single corn field. Also, the losses of maturing corn to a few pheasants are not significant when compared to the losses that occur during the fall combine harvest (average 6 percent of the entire field).[2]

Dust bathing in irrigation furrows seems to be regarded more as a nuisance, and is usually detected before serious damage occurs to the crop. Most farmers appear to have accepted this problem in stride and deal with it in their own way. The number of complaints have decreased over the years, possibly as a result of the advent of automated sprinkler systems. Pheasant damage to other crops are relatively few and infrequent. Table 4.2 shows the kinds of complaints received in recent years.

Surprisingly, skunks comprise a sizeable portion (5 percent) of recorded wildlife complaints in the Basin. Primarily these are little more than nuisances; quite a number arise in residential areas when an animal takes up residence under a house or outbuilding.. Complaints arising from all other species of wildlife amounted to about 12 percent of the records and span a wide variety of problems.

Serious offenders of crops include mainly coyotes, waterfowl, and pheasants. Although crop losses or increased production costs from these animals are perennial, widespread and believed to be economically significant, virtually no attempts have been made to estimate either the extent of damage or dollar losses. At best, wildlife agencies must rely on seat-of-the-pants guesses and the honesty of landowners when the extent of damage must be estimated. Neither of these methods hold up well under the stringencies of objective analysis. Consequently, the agencies opt for an easier alternative: a simple talley of complaints. It follows then that the success of wildlife control programs is measured by the number of complaints received and, to a lesser extent, the number of target animals removed.

As far as determining economic losses to crops in the Basin, the best to be offered at this point is a few examples based on damage claims submitted to FWS. These examples serve only to illustrate that dollar losses to farmers can be potentially high. Table 4.3 shows damage estimates for the years 1977 to 1980. Acreage figures are either contained in FWS records or, when unreported, are assumed to be

[2] J. Benson, personal communication.

Table 4.3.—*Estimated costs of crop damage by wildlife based on complaints received during 1977-1980 in the Columbia Basin, Washington (data are incomplete and do not represent total losses)*

Year	Damaging species	Crop affected	Total acres damaged	Potential damage cost[a]
1977	Geese	Wheat	390	$86,607
1977	Geese	Irrigated pasture	50	4,230
1977	Mallards	Corn	260	76,619
1978	Geese	Wheat	354	101,943
1978	Geese	Alfalfa	536	133,665
1978	Mallards	Corn	190	57,674
1978	Starlings	Sunflowers	40	6,067
1979	Geese	Wheat	200	66,480
1979	Mallards	Corn	160	62,174
1980	Geese	Wheat	725	240,990[b]
1980	Geese	Alfalfa	200	74,672[b]
1980	Geese	Peas	40	18,648

[a] Based on crop yields and prices as given in yearly Crop Report Summary Sheet, Columbia Basin Project, as supplied by Bureau of Reclamation, Ephrata, Washington.

[b] Costs for 1980 are based on 1979 farm prices.

40 acres as is used in FWS computations.[3] Estimated costs of damage to farmers as shown here are highly inflated for several reasons. Probably the two most important biases hinge on estimates of total acres damaged and the extent of loss within the damage area. Damage costs in table 4.3 reflect an assumption of 100 percent crop loss within the damage area. Control agencies rarely make onsite measurements of damages, so there are no "averages" to be utilized here.

As has been mentioned previously, actual damage to winter wheat by geese never happens on as large a scale as implied by table 4.3. Indeed, soil fertility may be improved by goose defecation to the extent that wheat production may be increased. We know that losses to standing corn by ducks are limited to ears near the bottom of stalks and to fallen stalks. The most severe losses likely occur in corn fields providing cattle forage. Thus, table 4.3 represents an extreme in losses which seldom, if ever, occur. Still, if we assume only 50 percent loss in damage areas, the price tag of wildlife runs high and can be a serious setback to the farmer.

ASSESSMENT PROBLEMS

At the outset of this study, it was believed that realistic appraisals of crop damage by wildlife could be gleaned from existing agency records. Review of the files, however, revealed otherwise; existing records raised more questions than they answered.

First of all, the question of what constitutes damage by wildlife lacks clearcut definition. Such a question seems as though it should have a ready and simple answer. Yet if one probes deeper, damage and losses are often a matter of individual perception and perspective. As such, they inherently vary as widely as do the personalities involved. While some situations so obviously result in a loss to the farmer, even to the eyes of the untrained, other damage claims against wildlife may be based on superficial evidence and erroneous interpretations. The issue of crop damage can often become a highly charged, emotional issue, out of scale with the degree of loss. While one landowner may be willing to sustain small losses as a matter of wildlife enjoyment, the mere presence of wildlife to another portends nothing short of economic catastrophe. Thus, the differences between damage and nuisance are often muddled.

It has been estimated that approximately 90 to 95 percent and 80 percent of coyote and beaver damages, respectively, are reported.[1] For other species, no one will hazard a guess. The claims on file cannot be used as a sample estimator since neither the sampling rate nor the amount of unreported damages are known.

Almost all field assessments fail to document the amount of area damaged. Moreover, the degree of loss within damaged areas is rarely, if ever, determined. These shortcomings preclude any kind of

[3] J. Coykendall, personal communication.

realistic appraisals. Although such data needs are well recognized, there has apparently been little further interest to fulfill the need.

Even with the severely limited data presently on hand, inconsistencies in damage records appear between and within wildlife control agencies. Recording methods have not been standardized between FWS and WDG. As a result, most of the data from these sources lack comparability. Within WDG, disparities in records are altogether too abundant between the field office and WDG headquarters.

SUMMARY AND RECOMMENDATIONS

By and large, the majority of landowners rate problems with wildlife per se fairly low on their list of concerns. Rajala and Shew (1978) [2] concluded after 2 years of study: *"It is the unusual Columbia Basin landowner who considers wildlife to have negative impact."* All agree, however, that they probably do experience some losses, but only infrequently do these losses become of sizeable consequence.

The most frequent complaint farmers had was in having to deal with recreationists – a consequence of having wildlife on their land. Based on present findings and those of Rajala and Shew (1978) [2], it appears that economic costs to most landowners are relatively small. Nevertheless, the costs of having wildlife on their land becomes a principal bone of contention during planning for wildlife enhancement and in negotiations for irrigation expansion.

At this time, we lack the necessary means to resolve the issue. Existing data are too meager to determine the magnitude of crop damages. The remaining alternative of conducting necessary studies was not feasible within the framework of the Columbia Basin Wildlife/Irrigation Study. Thus, this effort has failed in its objective to estimate the extent of damage to crops and production facilities in the Project. The fact that irrigators, water system managers, and wildlife agencies feel so strongly about wildlife costs makes it unlikely that a satisfactory resolution to the problem will be made in the absence of further study. We are hearing two somewhat opposing views from landowners, one of economic essence, the other an aesthetic reflection; wildlife increases farming costs, but landowners also enjoy having wildlife on their land. Water system managers tend to look solely at wildlife as an economic liability and as such would just as soon not have to bother with wildlife. Wildlife agencies naturally lean toward the desires of their constituency, but few will not knowledge the economically valid concerns surrounding the issue.

In light of present plans to expand irrigation in the Columbia Basin, the problem surrounding crop losses to wildlife should be investigated in considerable detail. Wildlife agencies cannot estimate the extent of damages with present data, nor can they do so at some future date unless large improvements are made in data collection methods. And it is very unlikely that even a few landowners can accurately describe their own losses. We urge that intensive study be given to estimating wildlife damages to agricultural production and that they be initiated as soon as possible. In the interest of both agriculture and wildlife, decisions should be forestalled until a better, more objective measure of wildlife damage can be obtained.

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Chapter V

AQUATIC STUDIES IN THE COLUMBIA BASIN PROJECT

Wallace E. Tillett

AQUATIC STUDIES IN THE COLUMBIA BASIN PROJECT

Fish production increased dramatically throughout the Columbia Basin Irrigation Project (Project) with the creation of new waters. An intensive trout fishery was established in numerous seep-formed lakes whose morphologic and limnetic characteristics offer many types of aquatic habitat. Project reservoirs provide year-round angling for a variety of sportfish and account for thousands of man-days of recreation annually.

In recent years, a downward trend in fish production has been observed within the project despite management efforts to the contrary. Some factors accounting for declining production are known, but many are not. The goal of this study was to determine the relationship between irrigated agriculture and fish production, and to provide information leading to the development of sustained, high-quality fishing in the Columbia Basin and future irrigation projects.

The broad objectives of this study were to identify, measure, evaluate, and incrementally analyze the response of fish to specific habitat features and facilities produced by, influenced by, or which accompany irrigation development in eastern Washington.

CLASSIFICATION OF WATERS

The study waters are classified according to the following physiographic characteristics: (1) whether naturally occurring or artificially created; (2) whether static water or a flowing water course; and (3) whether good, average, or poor fishery water. These features provide a relatively simple, straightforward approach for classification purposes. Only (3) above presents subjective choices.

Identification

All waters lying within the geographic boundary of the Columbia Basin, Kittitas, and Yakima irrigation projects were located using three principal references: (1) Lakes of Eastern Washington (Wolcott 1973) [1], (2) Merrill Spence, Regional Fisheries Biologist, WDG (Washington Department of Game), Ephrata, Washington, and (3) personnel of the USBR (Bureau of Reclamation), Ephrata, Washington.

Many wet areas, such as marshes and shallow seep lakes, in the above references were omitted from this analysis because our primary concern deals with waters which either are or have in the past supported a fishery. A number of waters were identified which lie outside the boundary of irrigation development. They are not influenced by irrigation facilities or development and represent controls for comparison.

Classification

In order to meet the study objectives, all waters were classified according to specific project and morphometric features. Included were the type of irrigation influence, size, and age of each water. These categories were subclassified according to fish growth as either good, average, poor, or none. This method of classification is direct and provides a logical means of comparing the many variables to be examined from each group of waters. All waters considered for study were classified according to features defined in appendix C.

STATIC WATERS

More than 400 ponds, lakes, and reservoirs lie within the Project boundaries. Many of these waters were planned Project features, but a greater number were formed incidentally as a result of rising ground-water levels. Before development of the Columbia Basin Project, few naturally formed ponds and lakes existed in this area. The majority of these waters supported a spiny-ray fishery with yellow perch and largemouth bass, the dominant game fish species (common and scientific names are listed in the appendices). Exclusively trout waters were limited to a few lakes prior to 1950.[1] This number has increased to about 100 as a result of the formation of numerous isolated seep lakes which are stocked annually with trout by WDG. Waters directly connected to irrigation canals, wasteways, and/or laterals are managed as a mixed species fishery out of necessity. As a group, waters directly influenced by irrigation comprise the largest surface area in the Project. Waters not influenced by irrigation which existed before the Project began account for the least amount of surface acreage.

The objectives in this portion of the study are twofold. First, to determine what effects irrigation development and operation have on the aquatic environment, specifically the fishery. Second, use this information to develop a mathematical model to predict fish productivity in future irrigation projects based on the physical, chemical, and biological characteristics of project waters. Both objectives draw

[1] M. Spence, personal communication.

from a common source of data on specific physical, chemical, and biological variables from three groups of waters. The three groups of waters are separated by irrigation influence as defined earlier. Group I is impounded waters directly affected by irrigation. Group II is seep-formed waters that are indirectly affected by irrigation. Group III is also seep-formed waters that are indirectly affected by irrigation but do not support fish life.

Appendix D lists the 32 lakes selected for study; 13 in group I, 16 in group II, and 3 in group III. Two lakes were subsequently dropped from the study. Keechelus Lake, belonging to group I, was not included in the final analysis because this impoundment receives drainage from a predominantly granite-quartz basin. This results in much differing water chemistry for this lake as compared to Columbia Basin lakes which drain basalt formations. As a result, significantly different biological communities inhabit these waters, making comparisons of irrigation influence and productivity difficult. White Bluffs Lake, a group II water, was dropped after completely drying up in the third year of study.

The succeeding presentation describes the collection and measurement of physical, chemical, and biological variables which are the basis for analyses pertaining to the aquatic investigations.

Methods and Materials

Physical Measurements

Morphometry

The morphometry of each impoundment was established using standard survey techniques (Lagler 1956) [2]. The following morphometric features were computed from contour maps of each site: (1) area (A); (2) volume (V); (3) mean depth (Z); (4) maximum depth (Z_m); (5) shoreline length (L); (6) shoreline development (D_L); (7) bottom slope (Z_r); and (8) development of volume (D_V). A definition for each feature is presented in appendix E.

Chemical Measurements

Water Chemistry

A 1-gallon sample of water was collected near the surface of each site at four different times during the study; June 1976, May and October 1977, and July 1978. Some lakes were sampled at midwater and maximum depth to check for chemical homogeneity. Water samples were transported to the laboratory in sterile plastic containers. Analyses were performed by the Washington State Department of Social and Health Services, Regional Chemical and Pesticide Laboratory, Wenatchee, Washington. The time between collection and analysis varied from a few days to 3 weeks with the majority being processed within 1 week. The following variables were measured: specific conductance, hydronium ion (pH), alkalinity, calcium hardness, silicon dioxide (SiO_2), potassium (K), calcium (Ca), magnesium (Mg), bicarbonate (HCO_3), carbonate (CO_3), sulfate (SO_4), chlorine (Cl), nitrite (NO_2), nitrate (NO_3), phosphorus (P), sodium (Na), and total dissolved solids (TDS).

All variables were measured using standard procedures (American Public Health Association 1975) [3].

Sediment Chemistry

The purpose of analyzing lake sediment was to determine if the level of nitrogen and phosphorus were indicative of nutrient abundance in the overlying waters. This also provided another dimension for comparison among lakes with regard to nitrogen and phosphorus of the sediment and the effect on productivity.

Sediment samples were collected with a gravity corer equipped with plastic liner. Thirty-two cores were collected, one from the center of each lake. Cores were capped at each end, labeled, packed in ice, and transported to the Environmental Engineering Laboratories at Washington State University. The cores were maintained at 4 °C (39 °F) until they were extracted.

Most cores were extracted in three sections, 0 to 2.0 inches, 2.1 to 6 inches, and a section greater than 6 inches. Some cores were extracted from areas where bands of sedimentation or varves gave an indication of different materials. Samples were obtained from each section for determination of total and orthophosphate, Kjeldahl nitrogen, nitrates, nitrites, and ammonia following standard procedures (American Public Health Association 1975) [3].

Biological Measurements

Interest in aquatic productivity centered upon the fishery and those invertebrates cropped directly by the fish. This approach was dictated by the need for simplicity and funding constraints. Consequently, each lake was sampled for diversity of benthic and zooplankton invertebrates and fish species composition, length, and weight. Estimates of relative abundance were computed for each species by their frequency of occurrence.

Benthic Invertebrates

Each site was sampled twice during 1977 for benthic invertebrates. Substrate samples were taken along transect lines extending from shore toward the lake center. Three equidistant transect lines were selected around the periphery of each lake in order to sample different substrate types. An Eckman sampler was used to collect a pair of substrate samples at each depth stratum along the transect line. Depths sampled were 1, 5, and 10 feet, and each 10-foot increment thereafter to the maximum depth of the site.

Identification of benthic invertebrates was contracted to Dr. Garrell Long, Department of Entomology, Washington State University.

Zooplankton

Zooplankton were sampled on three occasions during the study, August 1977, and March and June 1978. Three vertical hauls of 15 feet and one horizontal tow of approximately 300 feet were made on each sample date using a Wisconsin style plankton net.

Organisms were keyed to species by Dr. Martin Harris, Bellingham, Washington, and ranked by frequency of occurrence using subsamples of the total catch from each lake. Identification was limited to cladocerans and copepods as these organisms are considered to be more important to the diet of game fish.

Fish

Four types of gear were used to collect fish from static waters: angling, gillnet, electroshocker, and Lake Oneida trap.

Beginning in 1977, fish were sampled biannually to determine their seasonal growth and condition factor. The months of May to June and September to October represented the spring and fall sampling periods, respectively. Fish were weighed to the nearest gram and measured for fork-length in millimeters. This information was used to compute the relative condition of a fish which is a measure of robustness. Condition factor was computed as follows:

$$K = (W \times 10^5) / L^3$$

where:

K is the condition factor,
W is fish weight in grams,
and L is fish length in millimeters.

The condition factor is a useful index of fish response to environmental conditions. Fish populations that are thriving will display high values of K. Significant changes in environmental attributes (e.g., water quality, food supply, fish population density) may be reflected by an increase or decrease in K. Condition factors for trout are not comparable with those of most spiny-rayed fish because of differences in body configuration. Comparisons of fish growth were restricted to yellow perch in mixed species waters and rainbow trout in trout-managed lakes.

Results and Discussion

Morphometry

The eight morphometric variables generated from contour maps of each lake are listed in table 5.1. The data are presented in two groups by irrigation effect, group I for direct effect and group II for indirect effect. These values are approximations of average annual values because of changes in seasonal water-level fluctuations. However, they are sufficiently accurate for comparison. Two of the 32 lakes selected for study were not mapped for contours because of time limitations.

Group I lakes averaged more than twice the surface area than group II waters. This is because most directly influenced waters are artificial structures that have a planned storage capacity.

In comparison, group II lakes averaged smaller values for all morphometric features except volume development (D_V) and bottom slope (Z_r), indicating that these waters have flatter basins and steeper sides. These lakes are formed almost entirely by groundwater seepage and their morphometry varies little throughout the year.

Analysis of variance was used to test for significant differences in each morphometric variable between groups. The results, listed in table 5.2, show no significant differences in the mean values of the eight morphometric variables between groups I and II.

Water Chemistry

Mean values of water chemistry are listed in table 5.3 for each lake sampled. The data, arranged in three groups by irrigation effect, suggest the mean values of most chemical variables differ between groups.

Analysis of variance was used to test for significant differences among group means. Table 5.4 lists the test results for groups I and II, direct and indirect irrigation effect respectively, showing a significant difference among all chemical variables except SiO_2 and PO_4. For most chemical variables, the test statistic (F) is highly significant ($p \leq 0.001$).

Three lakes selected for study were known to be void of fish, presumably because of highly alkaline water conditions. These lakes comprise group III, indirect effect by irrigation, and lie adjacent to productive

Table 5.1.—*Morphometry of static waters grouped according to direct (group I) and indirect (group II) irrigation effect*

Location	Surface area (A)	Shoreline length (L)	Volume (V)	Mean depth ($\bar{Z}$)	Maximum depth (Z_m)	Shoreline develop. (D_L)	Volume develop. (D_v)	Bottom slope (Z_r)
	Morphometric variables[a]							
				Group I				
Mesa	50.0	2.1	250	5	12	2.1	0.42	0.72
L. Goose	50.0	2.1	1,300	25	75	2.2	.33	4.50
Soda	180.0	4.0	8,800	50	120	2.1	.41	3.90
Long	73.0	3.5	1,500	21	94	2.9	.22	4.70
E. Ancient	12.8	0.7	311	24	46	1.3	.53	5.46
Stan Coffin	56.0	2.4	370	7	20	2.3	.33	1.10
Evergreen	250.0	8.0	4,700	19	55	3.6	.34	1.50
Crater	26.0	1.6	530	20	45	2.2	.45	3.70
Billy Clapp	1,020.0	14.0	65,000	64	110	3.1	.59	1.50
Crater Slough	13.0	0.9	61	5	8	1.9	.60	0.96
				Group II				
Homestead	19.4	1.8	95	5	9	3.0	0.56	0.87
Lenice	94.0	2.3	780	8	23	1.7	.36	1.00
Trinidad	4.4	0.4	182	41	73	1.2	.57	14.78
Corral	77.0	3.5	2,400	31	62	2.9	.51	3.00
Migraine	18.1	1.7	179	10	51	2.8	.19	5.07
Poacher	0.7	0.1	13	19	443	1.1	.44	22.02
Beverly	3.3	0.4	53	16	41	1.5	.39	9.56
Heart	23.1	1.1	786	34	61	1.6	.56	5.38
E. Sage	9.1	0.5	173	19	40	1.2	.47	5.62
Harris	39.6	2.7	235	6	18	3.0	.33	1.21
Black Rock	10.3	0.6	99	10	16	1.4	.59	2.11
S. Teal	28.0	0.7	312	11	30	1.0	.37	2.41
Herman	34.0	1.5	495	15	40	1.8	.38	2.91
Quail	11.5	0.9	116	10	30	1.9	.33	3.76
L. Hampton	19.1	1.3	539	28	50	2.1	.56	4.86
N. Brookie	6.9	0.4	56	8	15	1.1	.53	2.42
Coffee Pot	320.0	7.5	12,000	39	75	3.0	.51	1.80
Jameson	620.0	5.2	15,000	24	64	1.5	.38	1.10

[a] Values are in English units: area (acres), length (feet), volume (cubic feet), depth (feet), and slope (percent). Shoreline and volume development are unitless ratios.

trout and spiny-ray waters. A test comparing their mean water chemistry values with that of group I are listed in table 5.4. All but four chemical variables, Ca hardness, SiO_2, Ca, and NO_2, differ significantly.

A third test compared mean water chemistry values of groups II and III. Results of this test are listed in table 5.4 and show that all chemical variables are significantly different between these groups except Ca hardness, SiO_2, and Ca.

Compared to temperature and oxygen extremes, water chemistry appears to be the more important factor controlling fish survival in the lakes studied. A threshold level was not determined, nor could one be found in the literature, but in general, when any of the following chemical parameters were exceeded, fish were absent: alkalinity, 700 p/m; NO_3, 4.0 p/m; PO_4, 2.0 p/m; Na, 400 p/m; TDS, 1,400 p/m; or pH, 9.1.

The only lakes likely to develop chemical concentrations in excess of these levels are isolated seep lakes. Chemical leaching from surrounding substrate combined with slow flushing times create conditions toxic to fish.

Lakes directly connected to irrigation return flows are continually mixing and flushing during the irrigation season. This prevents the buildup of chemicals to toxic levels in areas where the soil is highly alkaline. In these situations, connections with irrigation flows are absolutely essential to establishing and maintaining a fishery. A prime example of this is Soda Lake, located south of Potholes Reservoir. Prior to development, Soda Lake was uninhabitable by fish because of extreme sodium carbonate concentrations. Connection to Potholes East Canal resulted in favorable water conditions and the establishment of a mixed species fishery for perch, smallmouth and largemouth bass, walleye, and rainbow trout. Although Soda Lake is shut off from irrigation flows for 6 months each year (nonirrigable months), its water chemistry does not change appreciably. Interestingly, some of the better trout-producing seep lakes have chemical values approaching toxic levels. This raises questions as to the optimum range of chemical concentrations for fish growth. This will be addressed in the following section on productivity.

Sediment Chemistry

The purpose of lake coring was to determine if the abundance of certain chemical elements in the sediment, believed to influence nutrient levels in the overlying water, varied as a result of irrigation influence. Values of phosphorous and nitrogen occurring in the top 5 cm of sediment were tested for significant differences between groups using analysis of variance techniques. No significant differences were found in these chemical elements between groups I and II, direct and indirect irrigation effect, respectively. However, group III, waters void of fish, differed significantly in orthophosphorus, and orthophosphorus and NO_3 between groups I and II, respectively (table 5.5). Without inflow or outflow, static waters will reach a chemical equilibrium with that of the soil. In the case of group III waters, surrounding soils are highly alkaline, resulting in extreme chemical concentrations of the water. Soda Lake, mentioned above, would have qualified as a group III water prior to connection with Potholes East Canal. In fact, this lake was so alkaline it was mined for its salts in the late 1920's (Bennett 1962) [4]. Connection with irrigation flows brought this lake into fish production around 1952. Today it is one of the more heavily fished waters in the Project.

Zooplankton

A total of 62 species of Cladocera and Copepoda were identified from 30 lakes and are listed in table 5.6. Species most frequently sampled in group I lakes are *Bosmina longirostris*, *Daphnia schodleri*, and *Cyclops biscupidatus thomasi*, in that order. For group II lakes, *Cyclops biscupidatus thomasi* was most frequently sampled, followed by *Daphnia schodleri* and *Diaptomus novamexicanus*. In group III, *Diaptomus sicilis*, *Eucyclops agilis*, and *Daphnia schodleri* were sampled more often than any other species.

Group I waters averaged 14.8 zooplankton species, compared to 14.6 species for group II. Group III averaged 7.7 zooplankton species. Analysis of variance showed no significant difference in the number of species present between groups I and II. However, group III had significantly fewer ($p \leq 0.01$) species compared to the other groups, presumably because of high alkalinity.

Table 5.2.—*Analysis of variance for significant differences in morphometry of lakes receiving direct (group I) and indirect (group II) irrigation effect*

Morphometric variable[a]	Group I	Group II	Test statistic (F)	Significant difference
Surface area (A)	173.08	74.36	1.30	No
Shoreline length (L)	3.93	1.81	3.50	No
Volume (V)	8,282.20	1,861.78	1.74	No
Mean depth ($\bar{Z}$)	24.00	18.56	0.88	No
Maximum depth (Z_m)	58.50	41.17	2.32	No
Shoreline develop. (D_L)	2.37	1.88	3.16	No
Volume develop. (D_v)	0.42	0.45	0.28	No
Bottom slope (Z_r)	2.80	4.99	1.48	No

[a] Units of measure are: area (acres), length (feet), volume (cubic feet), depth (feet), and slope (percent). Shoreline and volume development are unitless ratios.

Table 5.3.—*Mean values of water chemistry for 30 lakes in the Columbia Basin, Washington, grouped by irrigation effect*[a]

Location	Sp.[c] cond.	pH[d]	Alkal.	Ca hard.	NO_3	SiO_2	Ca	Mg	HCO_3	CO_3	SO_4	Cl	NO_2	PO_4	Cation	Anion	Na	TDS
	Water Chemistry Variables[b]																	
Group I																		
L. Goose	403	8.0	114	63	1.0	8.2	25.1	17.3	139.1	0.0	51.3	15.0	0.01	0.11	3.1	3.8	30.0	272
Crater	492	8.1	147	75	1.3	19.4	29.8	38.2	171.8	1.0	44.4	26.5	.05	0.22	5.5	4.6	20.0	341
Crater Sl.	479	8.2	150	76	1.1	24.7	30.2	36.7	173.7	1.0	62.8	26.4	.07	0.07	5.4	5.1	20.0	347
Red Rock	565	8.1	160	97	2.8	23.7	38.6	33.0	195.1	0.0	93.6	26.4	.11	0.05	7.7	6.1	70.0	425
Long	417	8.1	137	66	0.9	9.1	26.4	21.1	167.2	0.0	47.8	12.1	.12	0.07	4.7	4.1	29.5	251
Evergreen	226	7.9	79	65	0.3	6.1	26.2	10.5	115.4	1.7	45.6	11.6	.01	0.03	3.4	3.2	7.6	152
Billy Clapp	149	7.4	51	52	0.2	3.2	27.6	6.4	63.0	0.0	20.3	0.2	.01	0.13	1.7	1.5	2.4	93
Mesa	614	8.2	161	77	2.3	15.1	30.8	35.3	196.3	0.0	112.8	27.4	.02	0.09	6.4	6.7	44.4	478
Soda	404	8.1	135	57	0.9	4.9	22.9	22.4	165.1	0.0	58.8	10.8	.03	0.12	4.3	4.3	31.0	230
E. Ancient	376	8.3	156	73	1.3	24.2	29.2	36.4	177.8	5.0	72.1	29.7	.04	0.08	5.3	5.7	19.8	303
Stan Coffin	515	8.3	174	82	0.9	25.0	32.8	34.6	180.8	9.3	68.5	27.3	0.04	0.09	5.9	5.6	31.7	301
Group II																		
Coffee Pot	339	8.3	140	63	0.9	4.3	25.0	15.2	160.9	3.0	36.5	8.2	0.04	0.10	3.9	3.8	30.6	191
Lenice	575	8.4	142	91	0.9	26.2	36.5	38.7	156.2	4.0	108.1	41.1	.02	0.05	6.7	6.3	39.7	365
N. Brookie	575	8.3	206	68	0.4	19.3	27.3	28.0	238.8	3.0	42.9	24.5	.02	0.09	6.9	5.6	58.3	345
Trinidad	526	8.1	155	82	1.3	20.7	32.7	41.6	180.4	1.0	64.1	27.6	.03	0.13	6.1	5.2	22.4	340
L. Hampton	503	8.2	164	69	0.5	21.9	27.7	26.6	189.1	4.5	56.3	25.5	.02	0.12	6.5	5.2	56.5	299
E. Sage	1,017	9.0	388	64	1.3	6.7	25.7	41.2	308.8	88.0	79.4	59.1	.01	1.02	11.3	11.7	152.0	457
Poacher	1,055	8.7	363	72	0.9	11.0	28.7	48.2	320.8	42.0	150.1	75.9	.01	1.05	14.6	12.4	214.3	555
Quail	1,174	8.8	279	51	0.7	14.1	20.5	68.2	226.3	52.5	202.0	198.0	.01	0.12	13.7	13.7	162.8	648
Jameson	1,858	8.8	549	40	1.2	4.5	16.0	61.0	473.5	76.0	280.0	100.0	.03	0.13	20.1	19.1	327.5	824
Homestead	545	8.4	223	50	1.1	19.8	20.2	40.2	244.6	5.5	41.3	9.9	.03	0.08	6.1	5.4	40.6	344
Harris	444	8.6	132	45	0.4	18.2	18.0	20.9	133.4	15.0	79.4	19.0	.02	0.08	5.7	4.9	70.4	279
Marco Polo	473	8.8	166	67	0.6	22.4	27.0	17.5	136.0	17.0	64.6	38.3	.01	0.09	5.6	6.0	64.1	275
S. Teal	503	8.5	174	51	0.5	20.4	20.5	27.3	186.8	7.0	85.0	26.0	.02	0.12	7.3	6.0	92.6	306
Heart	668	8.6	168	52	0.5	23.0	20.8	33.4	165.8	14.6	109.3	40.6	.02	0.06	7.2	6.9	79.6	348
Corral	754	8.3	230	67	0.7	26.5	27.0	42.9	262.0	5.0	116.4	30.7	.02	0.08	8.7	7.8	86.8	440
Herman	556	8.5	174	57	0.6	15.5	22.8	28.2	186.4	8.0	75.4	30.4	.01	0.05	6.4	5.9	68.1	346
Group III																		
Migraine	7,795	9.5	2,924	78	5.3	16.4	31.3	11.6	1,479.5	1,445.0	1,284.6	557.3	0.04	9.04	91.0	107.3	2,040.0	5,020
Beverly	1,827	9.5	768	39	9.4	24.6	15.8	9.3	427.5	312.0	79.2	101.1	.04	2.4	23.0	21.7	494.0	1,439
Black Rock	3,060	9.1	1,292	57	4.1	11.9	22.9	24.7	1,044.5	249.0	130.2	348.5	.04	8.2	42.4	35.5	901.0	1,915

[a] Groups I and II are direct and indirect irrigation effect, respectively. Group III is waters devoid of fish and indirectly affected by irrigation.
[b] All values listed are in p/m unless otherwise stated.
[c] Specific conductivity measured as μmho/cm^2.
[d] pH measured as the hydrogen ion activity in moles per liter.

Table 5.4.—*Analysis of variance test for significant difference*[a] *of mean values of water chemistry between groups I, II, and III static waters*[b]

Water chemistry[c]	Group I	Group II	Test statistic (F)	Group I	Group III	Test statistic (F)	Group II	Group III	Test statistic (F)
Spec. cond.	442.23	694.23	18.51 (***)	442.23	4,227.50	80.12 (***)	694.23	4,227.50	94.47 (***)
pH	8.07	8.51	33.88 (***)	8.07	9.37	149.62 (***)	8.51	9.37	52.95 (***)
Alkalinity	135.48	219.79	23.93 (***)	135.48	1,661.83	101.96 (***)	219.79	1,661.83	124.79 (***)
Ca hard.	72.25	62.44	4.17 (*)	72.25	58.33	3.05	62.44	58.33	0.33
NO_3	1.22	0.79	10.13 (**)	1.22	6.25	23.77 (***)	0.79	6.25	42.43 (***)
SiO_2	15.45	17.33	0.98	15.45	17.64	0.47	17.33	17.64	0.01
Ca	28.90	24.98	4.18 (*)	28.90	23.33	3.05	24.98	23.33	0.33
Mg	27.50	35.94	6.83 (*)	27.50	15.51	6.18 (*)	35.94	27.50	16.99 (***)
HCO_3	161.07	213.61	12.45 (***)	161.07	983.83	128.13 (***)	213.61	983.83	143.33 (***)
CO_3	1.80	21.16	16.31 (***)	1.80	668.67	53.59 (***)	21.16	668.67	71.78 (***)
SO_4	63.10	96.88	8.60 (**)	63.10	497.98	10.44 (**)	96.88	497.98	12.59 (***)
Cl	20.38	42.31	14.84 (***)	20.38	299.55	78.59 (***)	42.31	299.55	85.00 (***)
NO_2	0.05	0.02	12.49 (***)	0.05	0.04	0.16	0.02	0.04	10.75 (**)
PO_4	0.10	0.19	3.95	0.10	6.54	175.11 (***)	0.19	6.54	236.80 (***)
Cation	5.05	8.28	22.10 (***)	5.05	52.13	67.69 (***)	8.28	52.13	80.85 (***)
Anion	4.73	7.62	19.89 (***)	4.73	54.82	66.63 (***)	7.62	54.82	82.21 (***)
Na	28.30	93.11	28.67 (***)	28.30	1,145.08	72.85 (***)	93.11	1,145.09	89.98 (***)
T.D.S	290.41	387.07	5.62 (*)	290.41	2,791.50	48.62 (***)	387.07	2,791.50	59.16 (***)

[a] Value of F significantly different at $p \leqslant 0.05$ (*), $p \leqslant 0.01$ (**), $p \leqslant 0.001$ (***).

[b] Group I is direct irrigation effect, group II is indirect irrigation effect, group III is indirect irrigation effect and does not support fish life.

[c] Units of measurement are: specific conductivity (μmho/cm^2); pH (moles/L), all others (p/m).

Table 5.5.—*Analysis of variance test for significant difference*[a] *of mean values of sediment chemistry*[b] *between groups I, II, and III static waters*[c]

Sediment[d] chemistry	Group I	Group II	Test statistic (F)	Group I	Group II	Test statistic (F)	Group II	Group III	Test statistic (F)
Total P	909.18	940.38	0.07	909.18	689.67	1.35	940.38	689.67	1.05
Ortho P	1.06	2.13	1.27	1.06	13.16	9.54 (**)	2.13	13.16	9.50 (**)
NO_3	0.83	0.19	1.41	0.82	0.47	0.07	0.19	0.47	8.06 (*)
NO_2	0.10	0.13	0.75	0.10	0.10	0.00	0.13	0.10	0.20
NH_3	29.46	32.40	0.03	29.46	50.66	0.44	32.40	50.66	0.36
KJN[e]	657.91	771.63	0.10	657.91	1,193.00	0.90	771.63	1,193.00	0.50

[a] Value of F significantly different at $p \leqslant 0.05$ (*), $p \leqslant 0.01$ (**).

[b] Chemical values are for the top 2 inches of sediment.

[c] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is indirect irrigation effect and does not support fish life.

[d] All values are in p/m (parts per million).

[e] KJN is Kjeldahl nitrogen (includes ammonia and organic nitrogen, but does not include nitrite and nitrate nitrogen).

Table 5.6.—*Species of crustatcean zooplankton identified from 30 lakes in the Columbia Basin, Washington*

Order Cladocera	Order Copepoda
Family Leptodoridae	Family Temoridae
Leptodora kindtii	*Epischura nuvadensis*
Family Sididae	Family Diaptomidae
Diaphanosoma brachyurum	*Diaptomus ashlandi*
Diaphanosoma leuchtenbergianum	*Diaptomus connexus*
Latonoosis occidentalis	*Diaptomus leptopus*
	Diaptomus novamexicanus
Family Daphnidae	*Diaptomus oregonensis*
Daphnia galeata mendotae	*Diaptomus pribilofensis*
Daphnia middendorffiana	*Diaptomus pygmaeus*
Daphnia parvula	*Diaptomus reighardi*
Daphnia pulex	*Diaptomus sicilis*
Daphnia rosea	*Diaptomus pallidus*
Daphnia retrocurva	
Daphnia schodleri	Family Cyclopidae
Daphnia similis	*Cyclops bicuspidatus*
Daphnia thorata	*Cyclops bicuspidatus thomasi*
Ceriodaphnia acanthina	*Cyclops navus*
Ceriodaphnia lacustris	*Cyclops varicans rubellus*
Ceriodaphnia laticaudata	*Cyclops vernalis*
Ceriodaphnia pulchella	*Eucyclops agilis*
Ceriodaphnia quadrangula	*Eucyclops prionophorus*
Ceriodaphnia reticulata	*Eucyclops speratus*
Scapholeberis kingi	*Macrocyclops albidus*
Simocephalus vetulus	*Mesocyclops edax*
	Mesocyclops leuckarti
Family Bosminidae	*Orthocyclops modestus*
Bosmina coregoni	*Tropocyclops prasinus*
Bosmina longirostris	
Family Chydoridae	
Alona affinis	
Alona costata	
Alona guttata	
Alona quadrangularis	
Alona rectangula	
Alonella excisa	
Chydorus globosus	
Chydorus sphaericus	
Eurycercus lamellatus	
Kurzia latissima	
Leydigia quadrangularis	
Pleuroxus aduncus	
Pleuroxus denticulatus	
Pleuroxus procurvus	
Pleuroxus trigonellus	

Benthic Invertebrates

Benthic macroinvertebrates identified in substrate samples taken from 30 lakes in the Columbia Basin are listed in table 5.7. For most organisms, identification was limited to order or family with occasional identification to genus. This list of organisms points to the richness of benthic fauna inhabiting Basin lakes. The distribution of these invertebrates among the three groups of waters are listed in table 5.8. In this table, the number of organisms occurring in each order are listed by irrigation effect. Four orders, excluding the large number (3,540) of Annelidae sampled in Trinidad Lake, comprise 98 and 93 percent of the invertebrates found in groups I and II, respectively. They are, in decreasing abundance, Diptera, Gastropoda, Amphipoda, and Odonata, which are more commonly referred to as flies or midges, snails, freshwater shrimp, and dragonflies, respectively. Group III waters contained only three orders of invertebrates. Diptera comprised 74 percent of these organisms, all belonging to the family Chironimidae. Amphipoda and Annelidae made up the remaining 26 percent.

Table 5.7.—*Benthic macroinvertebrates sampled from 30 lakes in the Columbia Basin, Washington*

Order Gastropoda
- Lymnaea
- Physa
- Helisoma
- Gyraulus
- Menetus

Order Anacylidae

Order Pelecypoda

Order Annelidae
- Oligochaeta
- Hirudinea
  - *Erpobdella* sp.

Order Amphipoda
- Gammaridae

Order Decapoda
- Astacidae

Order Empheromeroptera
- *Ephemera* Sp.
- *Caenis* Sp.
- *Emphermerella* Sp.
- *Baetisca* Sp.
- *Paraleptophlebia* Sp.
- *Callibaetis* Sp.
- *Hexagenia* Sp.

Order Odonata
- Agrionidae
- Coenagrionidae
- Aeshnidae
- Libellulidae
- Gomphidae
- Cordulegastridae

Order Hemiptera
- Corixidae
- Notonectidae
- Belastomatidae
- Gerridae

Order Coleoptera
- Haliplidae
- Dytiscidae
- Elmidae
- Sphaeridae
- Chrysomelidae
- Hydrophilidae

Order Diptera
- Chaoborinae
- Ceratopogonidae
- Tabanidae
- Emphidinae
- Chironimidae
  - *Chironomuse* Sp.
  - *Pentaneura* Sp.
  - *Calopsectra* Sp.

Order Plecoptera

Order Trichoptera

Group II waters show the greatest diversity and abundance of invertebrates of the three groups. Two factors contributing to this are the absence of carp *(Cyprinus carpio)* and the stable ecological conditions characteristic of group II waters. With extreme efficiency, carp actively feed upon invertebrates most places within the aquatic environment. Also, carp are notorious scavengers, and once confined within these small lakes and allowed to proliferate, would soon destroy vegetative and substrate habitat critical to benthic invertebrate survival.

Because these waters are isolated from surface flows and direct pumping, they have a slower flushing time[2] and smaller water level fluctuation compared to waters directly connected to irrigation. These factors contribute to stable environmental conditions which allow for the establishment of more diverse floral and faunal communities.

Group III waters are also indirectly affected by irrigation, but show the least diversity and abundance of invertebrates, presumably because of limiting factors in water chemistry. Carp are not considered a factor here since fish cannot survive in group III waters.

Analysis of variance was used to test for significant differences in diversity and abundance of benthic invertebrates between groups. Two of the more well-known diversity indices used are Simpson's index:

$$\sum_{i=1}^{S} N_i(N_i-1)/N(N-1)$$

and the Shannon-Weiner index:

$$\sum_{i=1}^{S} (N_i/N \log_e N/N).$$

In each of these, S is the number of species or groups included in the index, N_i is the number of

[2] Flushing time: The average amount of time required for the water content of a lake to completely exchange with "fresh," incoming water (seepage and/or surface flow).

Table 5.8.—*Comparison of benthic macroinvertebrates occuring in group I, II, and III static waters*[a] *(the data are total number of organisms collected in each taxonomic order)*

Order	Group I	Group II	Group III
Gastropoda	109	727	–
Anacylidae	1	1	–
Pelecypoda	1	21	–
Annelidae	5	3,612[b]	5
Amphipoda	71	618	34
Decapoda	–	6	–
Ephemeroptera	–	77	–
Odonata	23	172	–
Plecoptera	–	1	–
Hemiptera	–	20	–
Coleoptera	–	35	–
Trichoptera	1	12	–
Lepidoptera	–	1	–
Diptera	342	1,607	109
Total no. organisms	558	6,910	148
Total no. samples	960	1,104	192
Average no./sample	0.6	6.3	0.8

[a] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is indirect irrigation and does not support fish life.
[b] Trinidad Lake provided 3,540 of the 3,612 annelids sampled in this group.

individuals of the ith species or genera, and N is the total number of individuals included in the index. Both indices reflect the likelihood that two individuals collected from an area will be in the same species or genera. Abundance was calculated as the ratio of the total number of invertebrates (regardless of species) to the total number of samples with invertebrates.

Of these measurements, only benthic invertebrate abundance differed significantly among the waters ($p \leq 0.05$). Abundance of invertebrates decreased as the irrigation influence increased (group III was not included in this test). Presumably this is because carp, sucker, and other bottom-feeding fish are abundant in waters directly affected by irrigation. Their impact through feeding on benthic communities is much greater than trout which are the only fish species found in waters indirectly affected by irrigation.

Differences in water chemistry may be a factor contributing to this decrease, but no significant difference existed between benthic invertebrate diversity and abundance and water chemistry when tested with analysis of variance.

Fish

Table 5.9 lists the number of fish of each species taken by all gear from static waters between 1977 and 1979. Scientific and common names of all fish sampled are listed in appendix F. Twenty fish species occur in group I, waters directly connected to the irrigation system. Group II, waters indirectly affected by irrigation, contained eight species, five of which came from one lake.

Yellow perch were the most abundant species found in group I. Rainbow trout are the dominant fish in group II as these waters, with the exception of Coffee Pot Lake, are managed by WDG as a single-species fishery. Because of this, no tests were made of differences in the diversity of fish species between groups of waters. It is assumed that both static and flowing waters, directly connected to irrigation flows, have predominantly spiny-ray fish populations. Also, any lake not directly connected to irrigation flows will be managed for trout, provided the lake is habitable.

In summary of this section, lakes directly influenced by irrigation have lower concentrations of most

Table 5.9.—*The number of fish of each species sampled during 1977 to 1979, from group I and II static waters, direct and indirect irrigation effect, respectively*

Species[a]	Group I	Group II[b]
Rainbow trout	238	1,046
Brown trout		3
Kokanee salmon	23	
Chinook salmon	3	
Lake whitefish	43	
Largemouth bass	125	56
Smallmouth bass	6	
Yellow perch	4,481	86
Black crappie	556	100
Pumpkinseed sunfish	181	145
Bluegill	16	
Sucker	68	
Carp	281	
Sculpin	11	
Peamouth chub	10	
Roach or Tui chub	380	
Squaw fish	5	
Walleye	6	
Yellow bullhead	20	
Brown bullhead	20	1
Redside shiner	1	c

[a] Scientific names of fish are listed in appendix F.
[b] All group II waters are managed exclusively for trout except Coffee Pot Lake which contains five spiny-ray species.
[c] Large population of redside shiner occurs in Jameson Lake (group II).

measured water chemistry variables, a lower abundance of benthic invertebrates, and greater diversity of fish species compared to indirectly influenced waters. Each of these factors can be attributed to management of these waters for irrigation purposes. However, these factors do not indicate what effects, if any, irrigation may have on fish productivity. That can only be determined through analysis and comparison of fish production of each group. This is addressed in the following section on productivity.

Perhaps the most obvious difference between the three groups of lakes is their appearance, a factor best measured on colored photographic film. Generally, lakes directly connected to irrigation had turbid or cloudy-colored water and a sparsity of aquatic plants, except cattails and rushes. Conversely, indirectly influenced lakes displayed clear water and abundant submersed aquatic plants, so abundant in some lakes as to be a detriment to the fishery by creating anaerobic conditions when plants decay during periods of prolonged ice and snow cover. Group III lakes, indirectly influenced by irrigation and void of fish, had cloudy-colored water and generally little or no aquatic vegetation, including cattails and rushes.

What effect these features have on fish productivity in group I and II waters is not completely understood. It can be argued that clear water allows sunlight to penetrate deeper into the water column. This in turn stimulates submersed plant growth which provides food and shelter for numerous invertebrate species. These organisms in turn provide food for the fish. Increased sunlight penetration also increases phytoplankton production which is the primary food source for zooplankton. These organisms are cropped directly by a variety of fish species. Thus, it can be shown that some of the better producing trout lakes in the project have turbid water and relatively few submersed aquatic plants. Conversely, some of the poorer trout producers are very clear and have abundant aquatic plant cover. These examples are not restricted to trout-only waters, as similar examples exist for spiny-ray lakes displaying both turbid and clear-water conditions.

Washington Game Department fishery biologists considered the effects of irrigation when developing the sport fishery in the Columbia Basin. In general, seep-formed lakes not connected to irrigation flows were managed exclusively for trout. Being free of competition from other fish species, these lakes produce the greatest poundage of trout per acre. Waters directly affected by irrigation receive trout plants also, but usually at a larger size and greater cost.

Productivity

The second study objective was to develop a mathematical model to predict fish productivity. A straightforward approach to define irrigation effects was the basis for establishing the three groups of waters. Defining aquatic productivity has not been as easy since a true measure of each lake's productivity was beyond the scope of this study. For simplicity and economy, waters were categorized as either good, medium, or poor producers, determined from growth rates or average condition factor of fish in each. To make comparisons between waters equitable, rainbow trout were used as the indicator of productivity in trout-managed waters. Because of their abundance, yellow perch were the species of choice in mixed-species waters.

Spiny-ray

To determine ratings of good, medium, and poor production in group I waters, the average condition factor of yellow perch was computed for each year sampled and the values ranked. The division between good, medium, and poor fish production required a subjective judgment based on the spread of these values. In theory, larger values of condition factor represent greater productivity. It was assumed that the level of production for each water remained fairly constant from year to year. However, upon comparison, the yearly average condition factor for a given site changed considerably. This affected the rank and consequently the level of productivity assigned each water. Some of the reasons for changing condition factors were inadequate numbers of fish sampled from each water and large variances in the weight and length measurements.

An average value can be changed considerably by the addition of a few large or small values to the sum. Also, an average gives no indication of changes over the range of lengths and weights. As an example, with poor environmental conditions, a population of fish can be declining in weight as they increase in length. Conversely, a more favorable environment would result in larger weights with increasing length. Differences in sampling effort or success could result in the average condition factor for both situations being equal, indicating no difference between fish populations. This inconsistency limits the usefulness of the "**average**" condition factor for grouping purposes.

A better indicator of fish response to the environment would be an instantaneous measure of condition factor over a representative size range, thus eliminating some of the bias mentioned above. This was accomplished by first calculating the predicted weight-length relationship from the data. Figure 5.1 illustrates the weight-length regression lines of yellow perch from six lakes sampled during 1977. The equation for each line was used to predict weight at each 10-mm increment of length between 130 and 230 mm. This size range included about 90 percent of the fish measured.

The resulting pairs of data were used to calculate predicted condition factors. These values were plotted against fish length and are illustrated in figure 5.2. By definition, productive waters have lines with positive slopes. A negative slope indicates a water of lower and possibly declining productivity. Three of the six lines shown have negative slopes. This indicates that, in these waters, yellow perch are not increasing in weight proportionate to length. These waters are ranked as poor producers.

Figures 5.3 and 5.4 illustrate similar graphs of yellow perch from 11 lakes sampled during 1978 and 1979, respectively. Except for two lakes, the slopes of the lines generally remain the same for each year sampled. Evergreen Reservoir changed from a negative slope in 1977 to a positive slope in 1978 and 1979. Long Lake maintained a positive slope in 1977 and 1978, but changed to negative in 1979. The reason for these changes may be due to sampling errors rather than changing environmental conditions in these waters. Even so, this technique results in much less variation in ranking compared to that obtained with the average condition factor.

Using the above technique, the relative productivity of each water was determined. A numerical rating of 1 to 11 was assigned to the slope of the lines in figures 5.3 and 5.4. The greatest positive slope received a rating of 1, and a value of 11 was given the greatest negative slope. This technique was also applied to fish condition factor at 230 mm of length of each water. A rating of 1 was given the largest condition factor and a value of 11 to the smallest. The sum of the ratings of both variables for each year represents the raw score for a lake. In turn, the raw score was ranked from 1 to 11 with the smallest value equal to 1.

The results are shown in table 5.10 for groups I and II, direct and indirect effect by irrigation, respectively, ranked according to the order of productivity of yellow perch. Unfortunately, there is only 1 water in group II with which to compare the 10 waters in group I. This makes comparisons between these groups inconclusive. Ideally, each group should have equal numbers of waters. This was not possible to achieve because of the occurrence of small numbers of group II waters containing perch in the study area. However, Coffee Pot Lake is a good example of a lentic environment not affected by irrigation. Of the six species of fish sampled in this lake, five are actively sought after by anglers. Pumpkinseed sunfish contribute little to sport fishing, but are probably an important item in the diet of resident largemouth bass. Yellow perch from Coffee Pot Lake are greater in weight for a given length than any other water sampled. There are no records of carp or suckers inhabiting this lake.

Trout

Trout-managed waters offered an easier, more accurate measure of productivity since most lakes are planted each year with fish of a known size. Estimated growth rates (grams/day) of rainbow trout in group II waters were computed by subtracting the weight of fish at planting and capture and dividing the difference by the number of days' growth. Carryover fish, i.e., fish greater than 1 year old, were determined from planting records and length-frequency analysis. Fish with more than 1-year growth were excluded from estimates of growth rates, the reason being that young, fast-growing fish were easily identified and displayed increases in

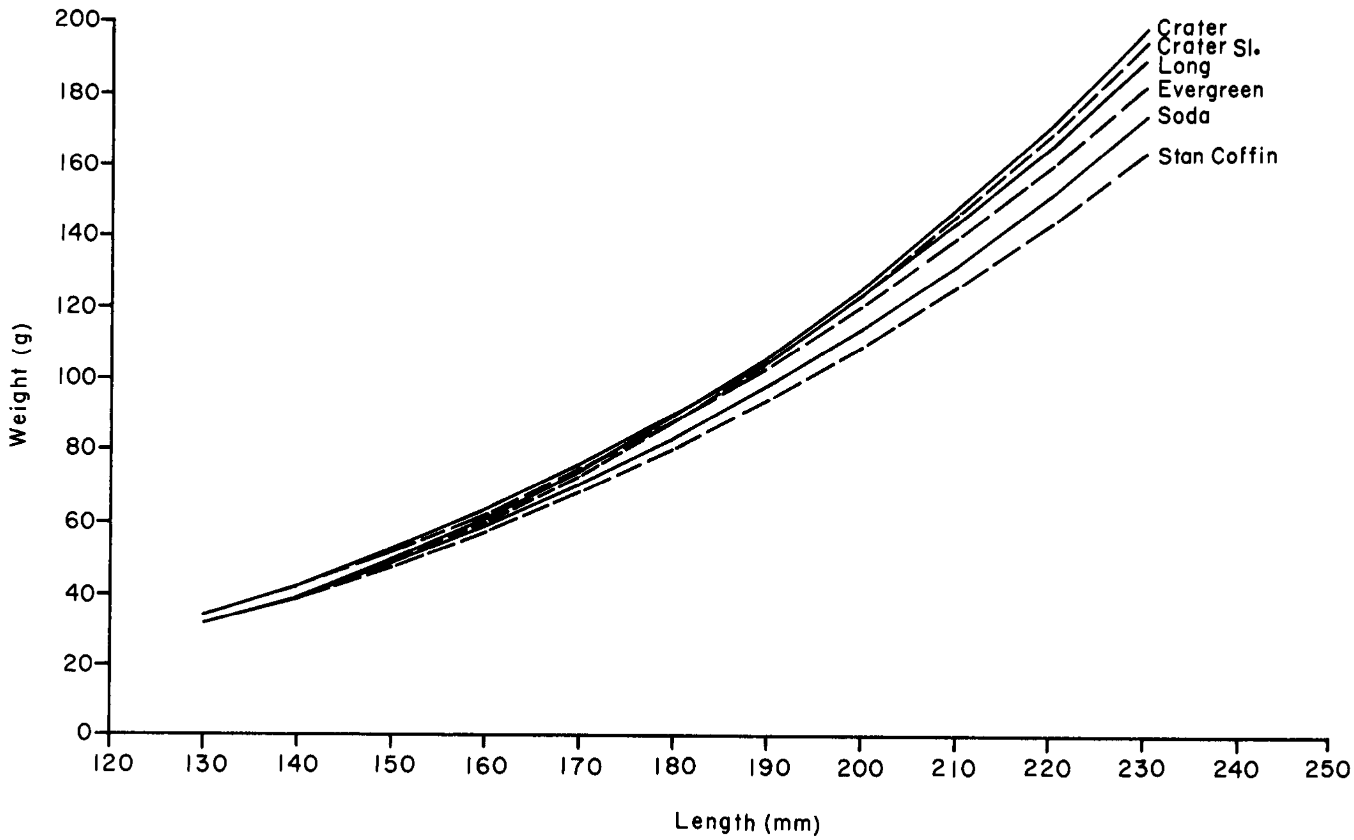


Figure 5.1.–Weight-length regression curves of yellow perch collected from six lakes in the Columbia Basin, Washington, during 1977.

weight proportionate to length. Fish greater than 1 year of age were difficult to separate by planting records and length-frequency analysis. Overlaps occurred where age 2- and 3-year (time after planting) fish were inseparable based on length, their age being determined from clipped fins. The use of fish less than 1 year of age reduced the risk of large errors in age estimates. Using linear regression, growth rates of trout from 15 lakes were estimated for the period 1977 through 1979. Not all lakes were sampled each year, and the total number of fish sampled in each varied from 7 to 99. The reasons for this are varied. In 1977, North Brookie Lake experienced a total winter mortality resulting from low oxygen conditions. Stan Coffin Lake was not stocked with trout in 1977. Trinidad Lake, a privately owned water, was closed to public access beginning in 1978. That same year, Poacher Lake experienced near total mortality to eye fluke, and Quail Lake was not planted. No trout plants were made in 9 of the 15 lakes listed during 1979. Those lakes receiving plants were sampled with angling gear. This resulted in fewer fish being captured compared to previous years when gillnets, live traps, and electroshocking equipment was used.

The results listed in table 5.11 are believed to fairly represent each lake's potential tc produce trout. This statement is made in view of the obvious lack of data in certain year-classes from 10 of the 15 lakes sampled. The first three lakes listed in table 5.11 have a history of consistently producing large trout. Likewise, lakes ranked fourth through eighth have always been considered as good to medium producers, and so on down the list. This professional judgment is taken from WDG biologists with as much as 20 years experience managing these waters.

The estimated weight gains (g/day) listed in table 5.11 under the column headed "All" were determined from linear regression analysis of all data points and not from an average of the year-classes. The lakes, ranked in decreasing order of production, show a difference of about eight times more growth between the best and poorest waters. Using breaks in the data, the division between good and medium lakes was set at 0.70 g/day; growth below 0.40 g/day rate as poor production.

The reasons for differences in fish growth between waters can now be examined. Environmental variables believed to significantly influence fish growth have been measured and discussed in some depth in the preceding section. These variables are lake basin morphometry, water and sediment chemistry,

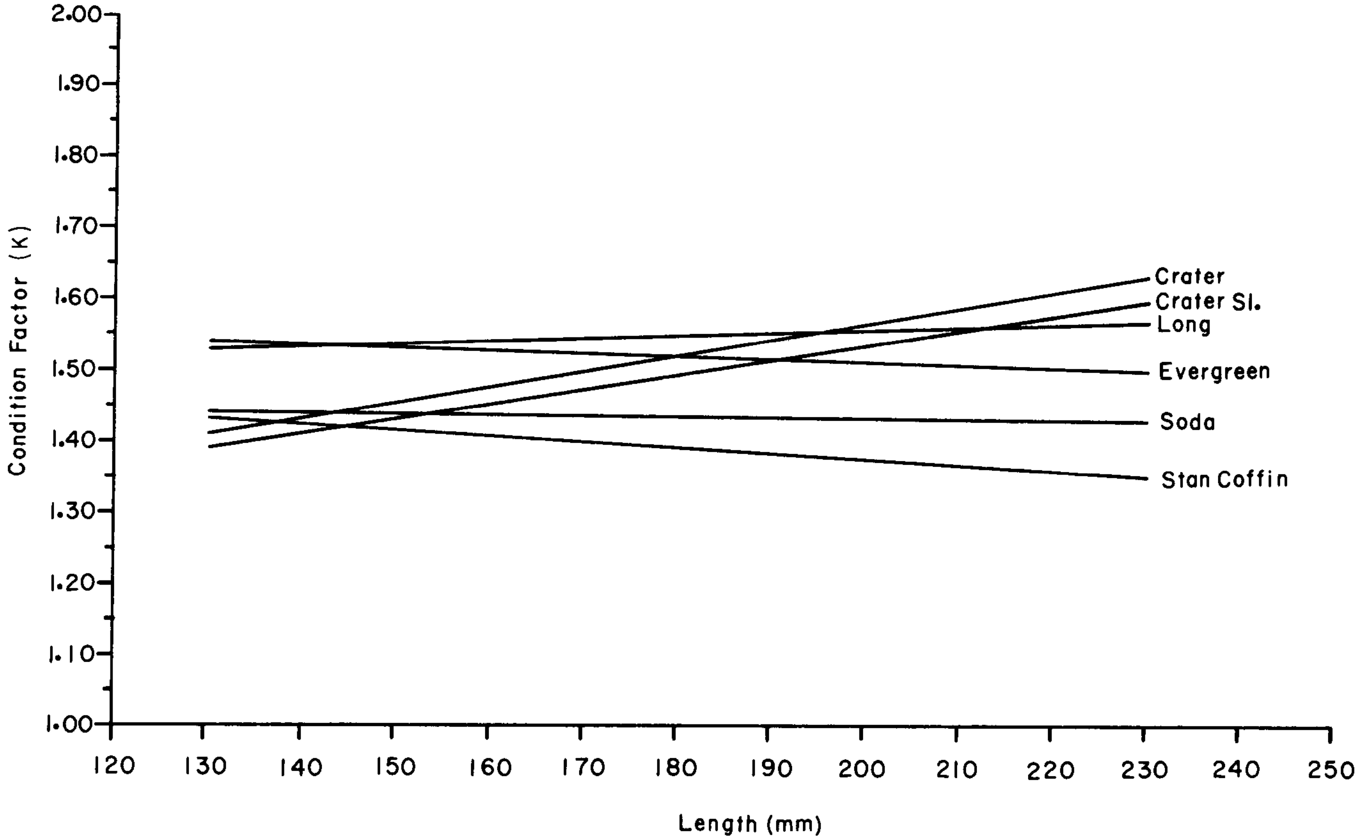


Figure 5.2.–Predicted condition factor of yellow perch between 130- and 230-mm length. (Fish samples were collected from six lakes in the Columbia Basin, Washington, during 1977.)

and diversity and relative abundance of benthic and zooplankton invertebrates.

Relationships between these variables and fish growth rates and condition factors were tested using analysis of variance techniques.

Morphometry

No correlation was found between perch or trout growth and lake morphometry. Of the eight morphometric variables measured, mean depth ($\bar{Z}$) was considered most likely to be correlated with fish growth. Earlier studies have shown mean depth inversely correlated with long-term fish production of the Great Lakes and other larger lakes in western Canada (Rawson 1955) [5]. The assumption here is that fish production is significantly related to biomass produced from sunlight penetrating the water column. In shallow lakes, more of the total water column is utilized for biomass production. As lakes become deeper, the photic zone is reduced, relative to the total lake volume, limiting the production of biomass and consequently, fish.

In the present study, mean depth was measured in 28 lakes, 10 in group I and 18 in group II. Table 5.2 shows the mean depths of these lakes average 24 and 19 feet for groups I and II, respectively. In either case, they are considered to be shallow lakes. Most lakes in group II have sunlight penetration to the bottom, opening the entire water column to biomass production. Because of this, it would be difficult to show a relation between mean depth and fish growth in these lakes if fish production is significantly correlated to sunlight dependent biomass. In most group I lakes, the photic zone is limited to the upper 5 feet of water because of turbidity. Here, too, mean depth would have little or no relationship to fish production dependent upon biomass produced in the photic zone.

Sediment and Water Chemistry

There are no significant differences between means of sediment chemistry variables and fish production (good, medium, and poor) in either spiny-ray or trout lakes (table 5.12). However, there are significant differences between means of water chemistry variables and fish production. Table 5.13 lists the results of analysis of variance tests showing that medium and poor spiny-ray lakes differ significantly in 7 of the 18 variables tested. Only one chemical variable

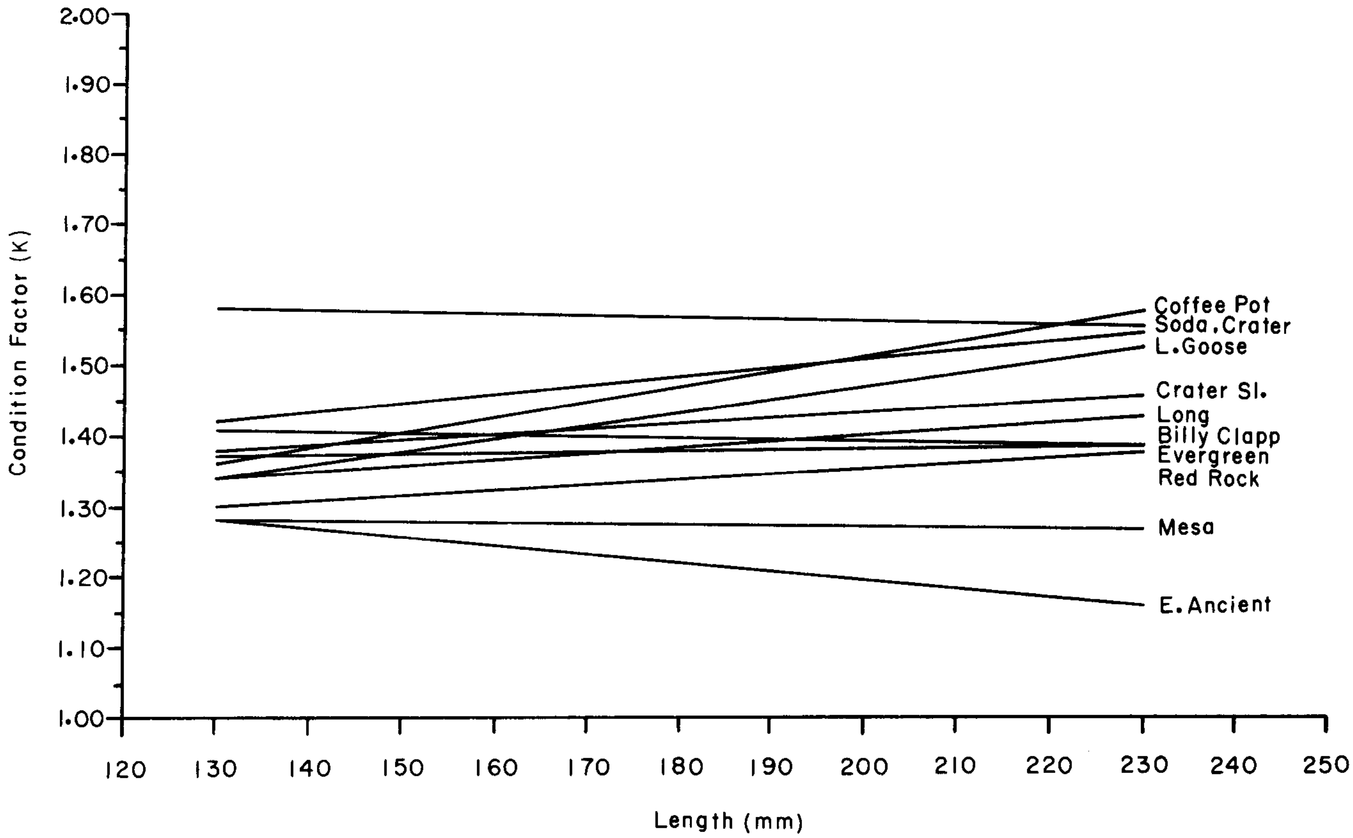


Figure 5.3.–Predicted condition factor of yellow perch between 130- and 230-mm length. (Fish samples were collected from 11 lakes in the Columbia Basin, Washington, during 1978.)

differed significantly between good and medium producing lakes, and there were no significant differences in water chemistry between good and poor spiny-ray lakes.

Based on these results, it might be assumed that the effects of water chemistry upon perch production are not linear, but restricted to a certain range. Above and below this range, production changes from good to poor and medium, respectively. This is shown in table 5.14, which lists the mean value of seven chemical variables that are significantly different between medium and poor producing lakes. For each variable, the mean value for good producing lakes lies between the range of medium and poor waters.

In developing a mathematical model to predict fish production, a rating might be assigned each variable to quantify its relative worth. Using the data from table 5.14, values of specific conductance (μmho/cm^2) might be rated as follows: (1) = 460; (2) = 400; (3) = 400-460.

Similar results are found in trout-managed waters. Table 5.15 lists 12 chemical variables that are significantly different between good and poor lakes, and no difference was found in water chemistry between medium and poor trout lakes. This means that good and poor trout-producing lakes are more similar in water chemistry than good and medium lakes. This makes it difficult to separate production into discrete categories on the basis of water chemistry alone.

Zooplanton and Benthic Invertebrates

Intuitively, an index of food organisms should be strongly correlated with growth rates. However, the data were not supportive since no significant differences were found between diversity and abundance of zooplankton and fish productivity. The same was true for benthic invertebrate diversity and abundance and fish productivity. However, it will be shown that weight gains of trout and benthic invertebrate abundance are somewhat correlated, as determined by linear regression analysis. The analysis performed in this section grouped the data into common units and tested for differences between group means using analysis of variance. Unless differences are highly significant, they will not be detected using this technique.

An alternative to diversity and abundance indices is to calculate the frequency of each species or group,

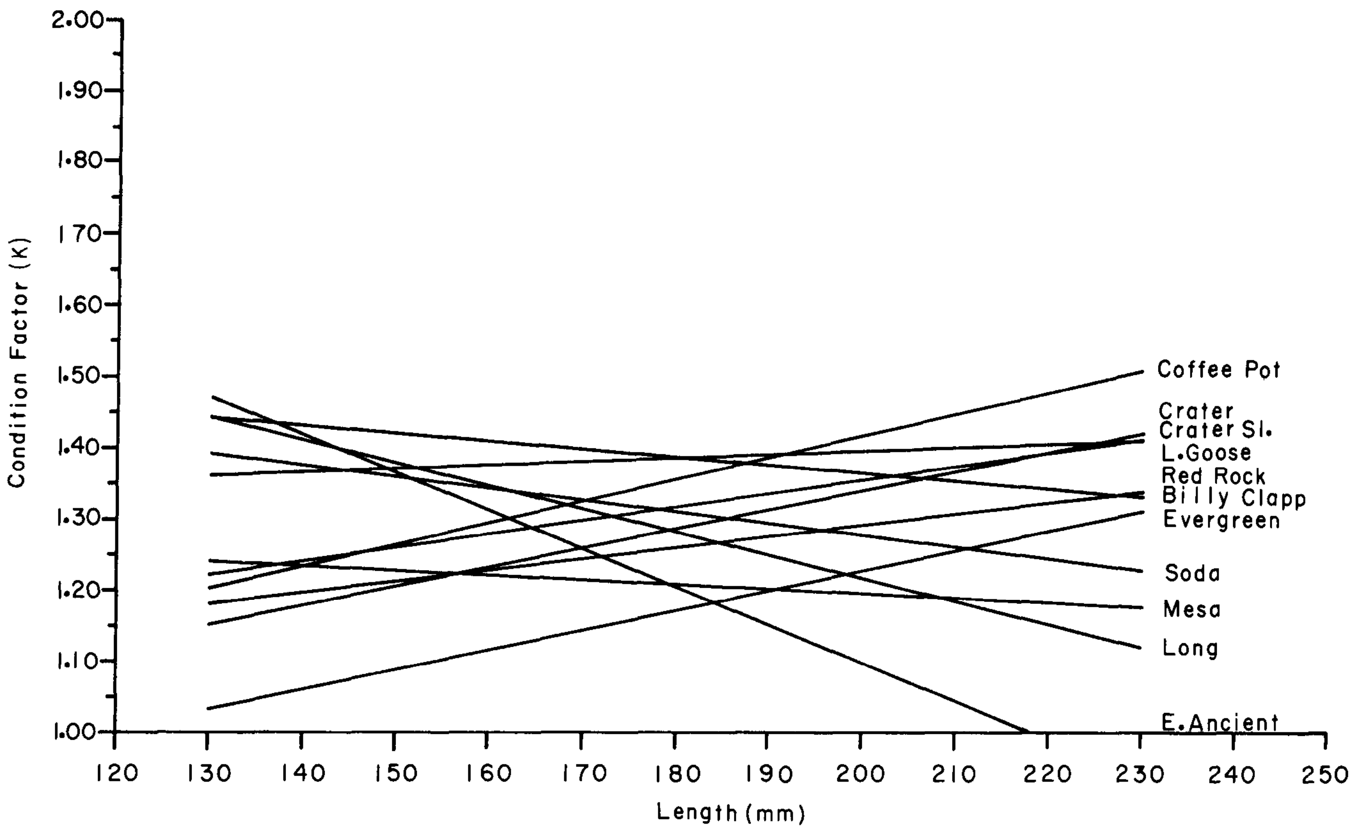


Figure 5.4.–Predicted condition factor of yellow perch between 130- and 230-mm length. (Fish samples were collected from 11 lakes in the Columbia Basin, Washington, during 1979.)

Table 5.10.–*Groups I and II static waters*[a] *ranked in decreasing order of productivity of yellow perch, based on the slope (B) of the length-weight regression and the condition factor (K) at 230 millimeters of length*

Location	Group	1977 B	1977 K	1978 B	1978 K	1979 B	1979 K	Totals[b] B	Totals[b] K	Totals[b] All	Final rank
Coffee Pot Lake	II			1	1	1	1	2	2	4	1
Crater Lake	I	1	1	3	2	3	2	6	4	10	2
L. Goose Lake	I			2	3	6	4	8	7	15	3
Crater Slough	I	2	2	5	4	4	3	9	7	16	4
Evergreen Reservoir	I	4	4	7	6	2	6	9	12	21	5
Red Rock Lake	I			6	7	5	5	11	12	23	6
Long Lake	I	3	3	4	5	10	10	14	15	29	7
Billy Clapp Lake	I			9	9	8	7	17	16	33	8
Mesa Lake	I			8	10	7	9	15	19	34	9
Soda Lake	I	5	5	10	8	9	8	19	16	35	10
E. Ancient Lake	I			11	11	11	11	22	22	44	11

[a] Group I is direct irrigation effect; group II is indirect irrigation effect.

[b] Data for 1977 not included in totals.

Table 5.11.—*Groups I and II static waters*[a] *ranked in decreasing order of productivity of rainbow trout and based on the estimated weight gains of fish planted in 1977 through 1979*

Location	Group	Estimated weight gains (g/day)				
					By year-class	
		1977	1978	1979	All	Rank
Trinidad	II	1.26	–	–	1.26	1
N. Brookie	II	–	1.20	–	1.20	2
Lenice	II	1.22	0.94	–	1.09	3
L. Hampton	II	0.64	1.01	0.86	0.82	4
Harris	II	0.86	0.74	–	0.80	5
Poacher	II	0.79	–	–	0.79	6
E. Sage	II	0.69	0.83	0.79	0.78	7
Quail	II	0.55	–	–	0.55	8
Homestead	II	0.84	0.42	0.63	0.50	9
Marco Polo	II	0.37	0.63	–	0.48	10
S. Teal	II	0.50	0.36	–	0.44	11
Heart	II	0.43	0.33	0.47	0.37	12
Corral	II	0.42	0.16	0.37	0.30	13
Herman	II	0.30	0.28	–	0.29	14
Stan Coffin	I	–	0.14	0.38	0.16	15

[a] Group I is direct irrigation effect; group II is indirect irrigation effect.

Table 5.12.—*Analysis of variance test for significant differences*[a] *between mean values of sediment chemistry*[b] *and fish production in spiny-ray and trout lakes in the Columbia Basin, Washington*

Sediment[c] chemistry	Fish production								
	Good	Medium	(F)	Good	Poor	(F)	Medium	Poor	(F)
Spiny-ray									
Total P	990	862	0.41	990	944	0.05	862	944	0.42
Ortho P	3.56	0.21	2.27	3.56	0.78	2.15	0.21	0.78	3.29
NO_3	0.17	2.62	1.59	0.17	0.13	0.35	2.62	0.13	1.64
NO_2	0.10	0.10	0.0	0.10	0.10	0.0	0.10	0.10	0.0
NH_3	84.27	11.47	4.32	84.27	24.02	2.80	11.47	24.02	0.22
KJN[d]	1,726	401	2.49	1,726	409	3.14	401	409	0.0004
Trout									
Total P	1,016	780	0.78	1,016	865	0.31	780	865	1.15
Ortho P	2.25	2.14	0.003	2.25	0.83	0.76	2.14	0.83	0.94
NO_3	0.18	0.27	0.68	0.18	0.16	0.08	0.27	0.16	0.99
NO_2	0.16	0.10	0.61	0.16	0.10	0.61	0.10	0.10	0.0
NH_3	26.80	28.05	0.003	26.80	18.10	0.18	28.05	18.10	0.26
KJN[d]	458	1,175	1.62	468	439	0.01	1,175	439	1.24

[a] There were no significant differences for any values of F in these tests.
[b] Chemical values are for the top 5 centimeters (2 inches) of sediment.
[c] Units of measure are p/m (parts per million).
[d] KJN is Kjeldahl nitrogen (includes ammonia and organic nitrogen but does not include nitrite and nitrate nitrogen).

Table 5.13.—*Analysis of variance test for significant differences*[a] *between mean values of water chemistry and fish production in spiny-ray lakes in the Columbia Basin, Washington*

Water chemistry[b]	Spiny-ray production								
	Good	Medium	(F)	Good	Poor	(F)	Medium	Poor	(F)
Spec. cond.	430	347	1.95	430	516	2.70	347	516	*6.38
pH	8.15	7.90	4.19	8.15	8.22	0.42	7.90	8.22	*7.35
Alkalinity	139	109	*4.55	139	158	3.20	109	158	*11.13
Ca hardness	69	72	0.07	69	73	0.23	72	73	0.04
NO_3	1.07	1.14	0.03	1.07	1.37	1.36	1.14	1.37	0.37
SiO	14.5	11.2	0.78	14.5	17.4	0.55	11.2	17.4	2.91
Ca	27.7	28.6	0.07	27.7	29.3	0.23	28.6	29.3	0.04
Mg	27.5	18.3	3.06	27.5	32.8	1.07	18.3	32.8	*7.44
HCO_3	163	138	1.87	163	181	1.84	138	181	*6.00
CO_3	0.13	0.5	0.70	1.3	3.8	1.25	0.5	3.8	2.32
SO_4	48.6	53.7	0.15	48.6	79.3	3.43	53.7	79.3	1.90
Cl	19.3	13.5	1.89	19.3	24.7	1.46	13.5	24.7	*5.17
NO_2	0.04	0.07	0.70	0.04	0.03	0.77	0.07	0.03	2.45
PO_4	0.12	0.07	1.90	0.12	0.10	0.32	0.07	0.10	2.12
Cations	4.73	4.51	0.07	4.73	5.55	2.07	4.51	5.55	1.36
Anions	4.37	3.87	0.61	4.37	5.63	3.76	3.87	5.63	*5.11
Na	24.8	29.0	0.15	24.8	31.8	1.83	29.0	31.8	0.06
TDS	288	231	0.78	288	328	0.44	231	328	1.95

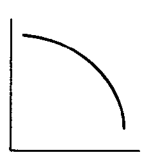
[a] Value of F significantly different at $p \leqslant 0.05$ *.
[b] Units of measure: specific conductivity (μmho/cm^2); pH (moles/L); all others (p/m).

N_i/N, rank the frequencies in order of decreasing magnitude, and plot the logarithm of each frequency against the logarithm of its rank. There are good arguments to suggest that the form of the plot has ecological significance.[3] The slope of the plot, as calculated by linear regression, was used as an index to the evenness of distribution of zooplankton and benthic invertebrates. No significant differences were found between this slope and fish production using analysis of variance.

Although the linear forms of the rank-frequency plots were not significantly different, there are a number of identifiable nonlinear forms, as follows:

Ia

Ib



II

The ordinate is logarithm of frequency; the abcissa is logarithm of rank for zooplankton species. In waters with type Ia distribution, a large number of different kinds of zooplankton are present, with many of these being relatively common. Thus, the distributions are rather linear and somewhat flatter overall than those of other types.

Type Ib distributions are very similar to Ia. They are fairly linear but have fewer species of which several are uniformly rare. Thus, several species of low frequency have equivalent rank, hence the flattening out at the tail of the curve.

Type II distributions are notably nonlinear. There are only a few relatively abundant species, but these could be considered "codominants." There are a few other species, but these are progressively rare. This causes the distribution to drop sharply down in the direction of higher ranks. Subcategories a, b, and c in type II are separated primarily by where the curve begins to plunge.

The rank-frequency distribution of benthic invertebrates was calculated in the same manner as described for zooplankton. The slope of the plot was tested for significant differences by analysis of variance. No significant differences were found.

The nonlinear forms of these plots are very similar to those described for zooplankton. All waters with

[3] G. Long, personal communication.

Table 5.14.—*Range of mean values of water chemistry for each type of spiny-ray production [a] water*

Water chemistry[b]	Spiny-ray production		
	Medium	Good	Poor
Spec. cond.	347.00	430.00	516.00
pH	7.90	8.15	8.22
Alkalinity	109.00	139.00	158.00
Mg	18.30	27.50	32.80
HCO_3	138.00	163.00	181.00
Cl	13.50	19.30	24.70
Anion	3.87	4.73	5.63

[a] Mean values of water chemistry all significantly different ($p \leqslant 0.05$) between medium and poor lakes. They are not significantly different between good and medium or good and poor lakes.

[b] Units of measure are: specific conductivity (μmho/cm^2); pH (moles/L); all others (p/m).

Table 5.15.—*Analysis of variance test for significant differences[a] between mean values of water chemistry and fish production in trout lakes in the Columbia Basin, Washington*

Water chemistry	Trout production								
	Good	Medium	(F)	Good	Poor	(F)	Medium	Poor	(F)
Spec. cond.	880	556	*11.51	880	604	3.01	556	604	0.99
pH	8.60	8.42	2.52	8.60	8.51	0.25	8.42	8.51	0.41
Alkalinity	267	192	*5.88	267	172	3.40	192	172	2.31
Ca hardness	65.4	61.2	0.34	65.4	549	0.93	61.2	54.9	0.71
NO_3	0.92	0.69	3.95	0.92	0.54	*6.06	0.69	0.54	0.67
SiO_2	15.2	22.2	*9.91	15.2	18.7	0.99	22.2	18.7	1.97
Ca	26.2	245	0.34	26.2	21.0	0.93	24.5	21.0	0.71
Mg	44.5	30.0	*9.58	44.5	30.4	*4.91	30.9	30.4	0.01
HCO_3	239	204	1.78	239	178	2.10	204	178	1.18
CO_3	37	7.8	*11.52	37	11	3.23	7.8	11	0.41
SO_4	127	73	*9.24	127	90	1.79	73	90	1.07
Cl	62.2	25.9	*14.73	62.2	34.8	3.21	25.9	34.8	1.81
NO_2	0.02	0.02	1.11	0.02	0.01	0.01	0.02	0.01	0.89
PO_4	0.31	0.09	*6.93	0.31	0.06	3.25	0.09	0.06	1.72
Cations	10.48	6.84	*10.92	10.48	6.77	*4.12	6.84	6.77	0.02
Anions	9.74	6.08	*12.43	9.74	6.33	3.88	6.08	6.33	0.23
Na	127	68	*7.38	127	73	2.24	68	73	0.23
TDS	470	334	*5.18	470	348	1.78	334	348	0.11

[a] Value of F significantly different at $p \leqslant 0.05$ *.

[b] Units of measure are: specific conductivity (μmho/cm^2); pH (moles/L), all others (p/m).

type Ia distributions are indirectly influenced by irrigation and either good or medium trout-producing waters. Type Ib distributions are mostly directly influenced and medium producers of spiny-rays, although trout in poorly productive waters are represented. Type II distributions are represented by subcategories a, b, and c as determined by where the curve begins to plunge. The points of greatest inflection are mostly medium and poor trout producers. Type IIb distributions are spiny-ray waters of mostly good and poor productivity. With the exception of Coffee Pot Lake, all are directly influenced by irrigation. Type IIc distributions are indirectly influenced and are void of fish. Table 5.16 lists these observations by irrigation influence and fish production associated with each type of distribution.

Table 5.16.—*Lakes*[a], *productivity*[b], *and irrigation influence*[c] *associated with benthic invertebrate rank-frequency curves of a given type*

Type of curve				
Ia	Ib	IIa	IIb	IIc
3 TIG	1 SDP	6 TIP	9 SDG	11 NIZ
5 TIM	4 SDM	7 TIG	21 SDP	14 NIZ
8 TIM	12 TIM	15 TIP	22 SDP	28 NIZ
13 TIM	18 SDM	19 TIG	23 SDM	
16 TIG		24 TIG	25 SDG	
17 TIM		27 TIM	31 SIG	

[a] Lake name and index number associated with each type of curve are listed in appendix D.
[b] Productivity: T = trout; S = spiny ray; N = no fish; G = Good; M = medium; P = poor; Z = no fish production.
[c] Irrigation influence: D = direct; I = indirect; N = none.

Modeling of Variables

Development of a mathematical model to predict fish productivity was the second study objective. The preceeding analysis was the first step in this process. The next step was to determine how much of the variation in fish productivity is explained by these variables. This is accomplished by step-wise linear regression analysis which compares each independent variable to the model coefficient of determination (r^2). The coefficient of determination shows the amount of variation in fish growth that can be accounted for (or replaced by) variation in the correlated variable. An independent variable was added to the model if it could contribute more to the model coefficient (r^2) than could any other independent variable already included. Two types of significance (or p value) levels are associated with each model. The model p-value indicates statistical significance of the overall, existing model, but each independent variable has its p-value as well. In many cases, the overall predictive ability of a model may be improved by adding independent variables, but the variables added may not each be very credible. Because of this, most of the models accepted have six or fewer independent variables, but each of these variables retained can, by itself, be considered a reliable predictor of productivity.

Development of a mathematical model to predict spiny-ray productivity was discontinued at this point. The reason for this was that condition factor ratings are, at best, only rough approximations of actual growth. Growth rates are needed for model building. Weight of perch in different age groups would be sufficient, and this information was available by aging individual fish through scale analysis. However, because of the enormity of the task (4,481 perch) and the amount of error associated with scale analysis, it was decided not to attempt the task.

Estimated weight gains of trout were regressed against 40 independent variables to determine if a correlation exists. These variables have been discussed previously. Three of the 15 trout lakes were not included in the regression analysis because of incomplete data sets.

Results of the step-wise regression are listed in table 5.17 for the six most significant variables. The analysis of variance is included for each of the six steps for comparison. In step 2, better than 90 percent (r^2) of the variation in trout growth is explained by two variables, the RFI (rank-frequency intercept) of benthic and zooplankton invertebrates. The significance levels (p-value) of both the model and the independent variables are very high (0.0001). As more variables are added, the model coefficient of determination (r^2) increases and changes in p-values occur for each independent variable. The p-value of the model remained the same, and at no point did the significance level of the independent variables drop below 95 percent.

Of the six variables, RFI of benthic and zooplankton invertebrates are the most important for explaining variations in weight gains of trout. The variables themselves are a measure of the richness of the most dominant invertebrate species inhabiting a lake. If time had permitted, a species list would have been prepared, as it relates to these findings.

The remaining four variables explain about 10 percent of the variability in trout growth. Of these, ammonia (NH_3) in the top 2 inches of sediment accounted for 4.8 percent. Ammonia is the major

Table 5.17.—*Analysis of variance of six independent variables regressed against weight gains of trout in lakes of the Columbia Basin, Washington*

Step 1	Variable: RFI—benthic		r^2 = 0.52538876		
	DF	Sum of squares	Mean squares	F	p-value
Regression	1	0.67978840	0.67978840	12.18	0.0051
Error	11	0.61408853	.05582623		
Total	12	1.29387692			
	B value	Std. error	Type II SS	F	p-value
Intercept	−0.82574987				
RFI-Benth	.73912909	0.21181298	0.67978840	12.18	0.0051
Step 2	Variable: RFI—Zooplankton		r^2 = 0.90362694		
	DF	Sum of squares	Mean squares	F	p-value
Regression	2	1.16918204	0.58459102	46.88	0.0001
Error	10	0.12469488	.01246949		
Total	12	1.29387692			
	B value	Std. error	Type II SS	F	p-value
Intercept	0.90634639				
RFI-Benth	.64325092	0.10126858	0.50310662	40.35	0.0001
RFI-Zoop	−.59196354	.09449093	.48939364	39.25	.0001
Step 3	Variable: Sediment ammonia		r^2 = 0.95342553		
	DF	Sum of squares	Mean squares	F	p-value
Regression	3	1.23361529	0.41120510	61.41	0.0001
Error	9	0.06026163	.00669574		
Total	12	1.29387692			
	B value	Std. error	Type II SS	F	p-value
Intercept	1.13700640				
Ammonia	0.00253852	0.00081832	0.06443325	9.62	0.0127
RFI-Benth	0.59544688	.07579098	.41328472	61.72	.0001
RFI-Zoop	−0.66880340	.07353855	.55381556	82.71	.0001
Step 4	Variable: Benthic abundance		r^2 = 0.98469780		
	DF	Sum of squares	Mean squares	F	p-value
Regression	4	1.27407775	0.31851944	128.70	0.0001
Error	8	0.01979917	.00247490		
Total	12	1.29387692			

Table 5.17.—*Analysis of variance of six independent variables regressed against weight gains of trout in lakes of the Columbia Basin, Washington*—Continued

	B value	Std. error	Type II SS	F	p-value
Intercept	0.75947406				
Ammonia	.00232155	0.00050040	0.05326994	21.52	0.0017
RFI-Benth	.82900442	.07388994	.31153010	125.88	.0001
Abundance	−.01165214	.00288176	.04046246	16.35	.0037
RFI-Zoop	−.63069439	.04569157	.47154460	190.53	.0001

Step 5 — Variable: Lake surface area — $r^2 = 0.99151673$

	DF	Sum of squares	Mean squares	F	p-value
Regression	5	1.28290062	0.25658012	163.63	0.0001
Error	7	0.01097631	.00156804		
Total	12	1.29387692			

	B value	Std. error	Type II SS	F	p-value
Intercept	0.71875936				
Surf. area	.00116071	0.00048932	0.00882286	5.63	0.0495
Ammonia	.00287223	.00046102	.06086280	38.81	.0004
RFI-Benth	.85662673	.05995642	.32008847	204.13	.0001
Abundance	−.01315883	.00238014	.04792795	30.57	.0009
RFI-Zoop	−.64674058	.03699320	.47926365	305.64	.0001

Step 6 — Variable: Sediment nitrates — $r^2 = 0.99585571$

	DF	Sum of squares	Mean squares	F	p-value
Regression	6	1.28851473	0.21475245	240.30	0.0001
Error	6	0.00536220	.00089370		
Total	12	1.29387692			

	B value	Std. error	Type II SS	F	p-value
Intercept	0.68551571				
Surf. area	.00131629	0.00037459	0.01103503	12.35	0.0126
Nitrates	−.17469083	.06969882	.00561411	6.28	.0461
Ammonia	.00343619	.00041445	.06143368	68.74	.0002
RFI-Benth	.87905788	.04614023	.32438961	362.97	.0001
Abundance	−.01418971	.00184335	.05295692	59.26	.0003
RFI-Zoop	−.63893312	.02910111	.46201427	516.97	.0001

nitrogenous end product of the bacterial decomposition of organic matter, and is also an important excretory product of invertebrate animals (Hutchinson 1957) [6].

Benthic invertebrate abundance accounted for 4.1 percent of the variability in trout growth. Abundance, as mentioned earlier, is a measure of the ratio of the total number of invertebrates (regardless of species) to the total number of samples with invertebrates. The average number of organisms per 0.25 square foot of lake bottom is a measure of richness. However, abundance is inversely related to weight gains, indicating that fewer organisms per unit area are better for trout growth. This may be an indication of food selectivity and that trout are feeding on a few species regardless of what is available.

Lake surface area, long suspected as a factor in productivity, accounts for less than 1 percent of the variation in weight gains. A significant contribution nonetheless, considering it was selected from 36 variables at step five of the regression process.

Nitrate concentration in the substrate explains 0.4 percent of the variability and is inversely related to trout growth. Water nitrates were found to be significantly correlated to trout standing crop in Wyoming streams (Binns 1976) [7]. Values between 0.15 to 0.25 p/m were best, and outside this range, trout standing crop decreased. Nitrate values in this study ranged from 0.10 to 0.58 p/m.

In summary, the best six-variable model accounts for 99.59 percent of the variability of trout weight gains. The model and the six independent variables are significant at the 95-percent level. The model is expressed mathematically as follows:

Weight gain (g/day) = 0.6855 + 0.0013 (surface acres) + 0.034 (substrate ammonia) + 0.8791 (RFI-benthic invertebrates) – 0.1747 (substrate nitrates) – 0.0142 (benthic abundance) – 0.6389 (RFI-Zooplankton).

A comparison of the two- and six-variable models is given in table 5.18. There is very little difference in the estimated weight gains between the two models. In fact, for practical purposes, the two-variable model is best, since it requires only two measurements to obtain an estimate with a high degree of accuracy.

As with all models, their reliability is only as good as the data used to construct them. While no attempt has been made to show the variability associated with the data used in this study, we believe the product is a useful tool.

FLOWING WATERS

Within the irrigation project lies a large network of water delivery structures. Canals, laterals, and drains total 3,529 miles, many of which are channelized concrete structures (USBR)1978 [8]. Some wasteways and drains have earthen channels which follow meandering courses similar to naturally created streams of the area.

Our objective in studying these waters was to determine those features significantly influencing fish growth and survival. This information will be used to assess potential fish production of future irrigation water delivery structures. Also by incorporating these features into the early design and operation phase of new projects, maximum fishery benefits can be achieved. The proposed East High extension of the Columbia Basin Irrigation Project will consist mainly of water delivery structures with only a few storage reservoirs. Few seep lakes are expected to form in this area.

Approximately 378 miles of channelized water delivery structures were sampled for fish and other variables at different times during the study. In addition, 145 miles of naturally occurring streams were surveyed of which 96 miles lay outside project boundaries.

Methods and Materials

Flowing waters within the project are grouped according to the influence of irrigation the same as static waters. Group I is water directly affected by irrigation and includes canal, drain, and wasteways directly connected at some point to an irrigation

Table 5.18.–*Comparison of the two- and six variable models for estimating weight gains of trout for Lenice Lake*[a]

Independent variable		Two-variable model		Six-variable model	
		Constant	Product	Constant	Product
Intercept		0.9063	0.9063	0.6855	0.6855
Acres	(94.00)			.0013	0.1222
Ammonia	(0.50)			.0034	0.0017
RFI-Benthic	(2.16)	.6433	1.3895	.8791	1.8989
Nitrates	(0.25)			–.1747	–0.0437
Abundance	(18.28)			–.0142	–0.2595
RFI-Zooplankton	(2.10)	–.5920	–1.2432	–.6389	–1.3417
Weight gains	(g/day)		1.0526		1.0634

[a] Average weight gains of trout as determined from captured fish equaled 1.09 g/day.

system. Group II includes wasteway and natural streams that change in level or flow resulting from ground-water seepage but are not directly connected to the irrigation system of canals and reservoirs. Group III consists of flowing waters not affected by irrigation operations representing naturally created streams.

Environmental variables believed to influence fish production were measured at various locations along the length of these waters. In general, sample locations were spaced at 1-mile intervals for channels less than 5 miles in length. At each location, from one to five stations were established. The length of each station depended upon the type of water being sampled. A station consisted of one of the following water types: plunge pool, pool, riffle, glide, or flat. The definition of each water type is given in the following section on morphometry. Not all water types were present at a given location. For example, canals and drains have channels that are mostly straight and lined with either concrete or compacted earth. Such features are artificially constructed and uniform in their morphometry throughout. Because of this type of morphometry, laminar flows in these waters classify as glides. Wasteways usually exhibit these characteristics at one or more points along their course. Where such uniformity exists, only one station was required for a given location.

Naturally occurring streams and most reaches of earthen wasteways and drains have greater morphometric diversity. This results in the formation of different water types requiring more sample stations. As previously mentioned, the length of a station depended upon the type of water being sampled. Glides are generally greatest in length, plunge pools the least. The length of most stations was held to less than 150 feet and consisted of six transect lines spaced equal distances apart and perpendicular to the channel. Transect lines were used to obtain average width and depth measurements. Permanent station markers made of 4-foot wood stakes were located above high water at the upstream end of each station.

Physical Measurements

Morphometry

Morphometric features were selected from criteria described by the USFS (US Forest Service) (Herrington *et al.* 1967) [9] and Wyoming Game and Fish (Binns 1976) [7] for stream habitat evaluation. The following features were measured at each station: (1) width; (2) depth; (3) substrate; (4) substrate color; (5) water type; (6) water color; (7) bank stability; (8) undercut banks; and (9) discharge. A definition of each is presented in appendix G.

Chemical Measurements

Water Chemistry

A 1-gallon sample of water was collected from the lower reach of each stream using sterile plastic containers. Streams receiving inflow from tributaries and drains were sampled at their upper, middle, and lower reach. Collection dates and type of chemical analysis were the same as static water samples. Sediment chemistry was not analyzed in flowing waters.

Biological Measurements

Standing crop or biomass is an instantaneous measure of the number or weight of organisms per unit area. It is a common way of expressing productivity and is the primary response index for evaluating habitat quality. Estimates of standing crop were computed only for fish in this study. Collections were also made of aquatic and riparian vegetation and aquatic invertebrates. Indices of species diversity were computed for the invertebrates but no estimates were made of their standing crop.

Aquatic and Riparian Vegetation

Aquatic vegetation was divided into general groups: (1) bulrush (*Scirpus* spp); (2) cattail (*Typha* spp); (3) duckweed (*Lemna* spp); (4) filamentous green algae; (5) water milfoil (*Myriophyllum* spp); (6) pondweed (*Potamogeton* spp); and (7) watercress (*Nasturtium* spp). Abundance of aquatic plants was visually estimated as the percent of channel covered by each group.

Riparian vegetation was classified according to the following types: (1) trees, (2) shrubs, (3) marsh grass, (4) upland grass, or (5) none. Abundance was visually estimated as the percent of both banks covered by each type of plant. The amount of bank used to make these estimates was a strip 10 feet wide and running the length of the station. If two or more plant types were present, they were listed in decreasing order of abundance.

Bank Cover

In addition to moderating water temperatures, the type and amount of riparian vegetation provides some important cover for fish. Bank cover was rated from one to four using criteria developed by the USFS (Herrington *et al.* 1967) [9] as follows:

1. Forested – Bank is medium to heavily covered or shaded by growth of tall trees or dense riparian vegetation;

2. Brush – Bank is bordered or shaded by growth of tall brush or dense riparian vegetation. Thinly

scattered tall trees may be present but are not the dominating feature;

3. Grass – Bank is medium to heavily covered with tall grasses and forbs or low shrubs, or a combination of these plants; and

4. Exposed – Bank is covered with scattered low grasses, forbs, or shrubs; or banks are barren of vegetative cover or a combination of these.

Drift Organisms

Aquatic insects and other organisms drifting freely with the current were collected with drift nets. Net material consisted of 200-micron Nitex screen cloth with a mouth opening 2 by 3 feet and tapering 60 inches to a 2-3/8-inch-diameter cod-end.

Organisms were collected at each location by placing a net in the stream for 10 minutes. Net placement was usually in the center of a glide and never exceeded 3 feet in depth.

Benthic Invertebrates

A Surber square-foot bottom sampler was used to collect benthic invertebrates in riffle areas at each location. Three square-foot samples of substrate were taken across the width of the stream and washed for organisms in screened buckets.

Fish

Each station was sampled for fish using a Smith-Root Type VII backpack electroshocker. Both ends of a station were secured with block nets to prevent fish escapement. Block nets measured 6 by 60 feet with No. 5 knotted netting.

Three passes were made through each station and fish removed on each pass for a population estimate (Zippin 1958) [10]. All fish were measured for fork length in millimeters and weighed to the nearest gram. Each fish species was identified by a numerical code. These codes are listed in appendix F. Figure 5.5 illustrates a data sheet used to record measurements at each station.

Results and Discussion

Physical Measurements

Morphometry

Table 5.19 lists by groups the length in miles of flowing waters surveyed both within and outside the Columbia Basin Irrigation Project. Group I is the largest with eight waters, seven of which were built specifically for transporting irrigation water. This group also accounts for 72 percent of the total stream miles surveyed. Groups II and III are about equal with three and four flowing waters and comprise 10 and 18 percent of total stream lengths studied, respectively.

It was not necessary to test for significant differences in morphometry between the three groups of flowing waters. Groups II and III are nearly identical in morphometry. Group I flowing waters are most always clearly distinguishable from the other two. Differences are very clear; and with the exception of Lower Crab Creek, all group I waters have structured channels throughout all or part of their reach. This type of channel morphometry results in a continuous glide with relatively few undercut banks and in many cases uniform width, depth, and substrate composition.

Conventional methods of classification rate streams on the ratio of pools to riffles with a ratio of 50/50 as ideal. What was not a riffle was classified as a pool. In this study, five water types were identified as frequently occurring throughout the length of most unchannelized streams. These five water types described in the methods section are plunge pool, pool, riffle, glide, and flat. Where channels have been allowed to seek their own course such as naturally created streams and specific reaches of Winchester and Frenchman Hills Wasteways, these water types are evident. The most abundant water type in wasteways are glides, pools, and flats, in that order. These features are determined by the terrain through which the water flows, specifically, a low gradient of predominantly sandy soil.

The lower half of Winchester Wasteway meanders considerably more than any other stream surveyed. This has resulted in the formation of pools and undercut banks at most bends of the channel. It also contributes to erosion of the sandy banks. Where riparian vegetation has been established and allowed to flourish, erosion is noticeably reduced.

Chemical Measurements

Water Chemistry

Mean values of water chemistry are listed in table 5.20 for the 20 streams. The data are grouped by common nomenclature such as canal, drain, wasteway, and stream to illustrate changes in water chemistry with changes in location and farming activities. For example, canals are listed in decreasing order from north to south. Main canal is located in the northernmost portion of the irrigation project receiving water directly from Banks Lake. Potholes Canal originates in the Project's central area and terminates in the southern reaches at Scootney Reservoir.

Stream																								
Stream									Surveyor									Date						
Location				Station of						Length (ft)					Start			Finish			minutes			
water width (ave)	water depth (ave)	water depth(max)	water color	substrate color	substrate type	bank slope	undercut(%)	stability(%)	overhanging vegetation	water type	channel type	channel slope	width of channel	aquatic vegetation	abundance % of channel	riparian vegetation	bank cover	drift sample no.	substrate sample no.	flow (cfs)	secchi depth (ft)	ph	dissolved oxygen	temperature (°F)

	PASS NO. 1 trout no. wt.(g) other no wt.(g)								PASS NO. 2 trout no. wt.(g) other no. wt.(g)								PASS NO. 3 trout no. wt.(g) other no. wt.(g)							
	fish sp	ln (mm)	wt (g)	age	fish sp	ln (mm)	wt (g)	age	fish sp	ln (mm)	wt (g)	age	fish sp	ln (mm)	wt (g)	age	fish sp	ln (mm)	wt (g)	age	fish sp	ln (mm)	wt (g)	age
time (sec)																								
pulse width																								
frequency																								
volts																								

Figure 5.5.–Data sheet showing variables measured at each stream station.

East Low Canal extends further south than any other flowing water but was sampled only in its northen reach.

The geology changes from predominantly basalt outcroppings in the north to deep sandy loam soil in the south. Accordingly, farming activity increases in a southerly direction. These two factors, soil type and agricultural activity, seem to affect water chemistry. The concentration of most chemical variables listed in table 5.20 increased the further south samples were taken. This is best illustrated in water samples taken from the upper, middle, and lower reaches of Crab Creek which receive no effect, indirect effect, and direct effect by irrigation, respectively. Natural streams such as Douglas, Wilson, and Almira Creeks have water chemistry similar to upper and middle Crab Creek.

Another noticeable difference in water chemistry listed in table 5.20 is chemical concentrations in earthen versus concrete-lined channels. Higher concentrations are generally found in earthen channels because of the leaching effect of certain chemicals from soils. Also, many drains and wasteways receive chemically enriched irrigation return flows. Concrete-lined canals do not change appreciably in water chemistry unless their route passes through a reservoir.

Analysis of variance was used to test for significant differences in water chemistry between types of irrigation effect. These tests were computed on the same data listed in table 5.20, but grouped according to direct, indirect, and no effect as groups I, II, and III, respectively. As such, the rearrangement of data to conform to this grouping was only slightly different from that listed in table 5.20.

Table 5.19.—*Miles of groups[a] I, II, and III flowing waters surveyed both within and outside the Columbia Basin Irrigation Project (most waters[b] were electroshocked for fish twice in the summer of 1978)*

Group	Location	Within	Outside
I	Drain 239	6	
	Drain 645	15	
	Misc. drains	10	
	Esquatzel W. W.[c]	20	
	Lind Coulee W. W.	10	
	Rocky Coulee W. W.	1	
	Winchester W. W.	25	
	Frenchman Hills W. W.	12	
	Lower Crab Creek	40	
	Main Canal	21	
	West Canal	88	
	East Low Canal	130	
II	Homestead Creek	4	
	Middle Crab Creek	38	
	Rocky Ford Creek	7	
III	Almira Creek		4
	Douglas Creek		17
	Wilson Creek		6
	Upper Crab Creek		69
	Total miles:	427	96

[a] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is no irrigation effect.
[b] Main, West, and East low canals were not electroshocked for fish.
[c] W. W. = Wasteway.

Only two chemical variables differed significantly between group I and II flowing waters. These variables are listed in table 5.21 as alkalinity and bicarbonate. There were no significant differences in water chemistry between groups I and III. Seven chemical variables differed significantly between groups II and III.

The results of these tests are believed to depend more on the grouping of waters than actual differences in water chemistry. Recall the differences in water chemistry of earthen versus concrete-lined channels discussed earlier. When grouping for direct irrigation effect, both earthen and concrete-lined channels are included in group I. This tends to average out the high and low chemical values thereby placing this group somewhere in the middle of the range of values of all groups. By definition, group II and III flowing waters are more similar in structure than group I waters. The differences in their water chemistry are probably caused by differences in soil chemistry since both groups are free of direct irrigation effect.

Biological Measurements

Benthic Invertebrates

Table 5.22 lists by scientific name the benthic invertebrates taken in substrate and drift samples from 20 flowing waters. Identification was made to genus and species where possible. Thirteen orders were identified.

Table 5.23 lists the number of organisms by order taken from group I, II, and III flowing waters. The average number of organisms per sample (substrate) is least for group I, directly affected waters and greatest for group III, no irrigation effect. Although they were not tested statistically, these differences appear significant. The amount of diversity also increases as irrigation influence decreases. Group I produced 9 orders of invertebrates while groups II and III produced 11 and 13, respectively.

Diptera were the most common invertebrate sampled regardless of irrigation effect. In general, this is

Table 5.20.—*Mean values of water chemistry for 20 flowing waters in the Columbia Basin, Washington*

Location	Sp. cond.[b]	pH[c]	Alkal.	Ca hard.	NO_3	SiO_2	Ca	Mg	HCO_3	CO_3	SO_4	Cl	NO_2	PO_4	Cations	Anions	Na	TDS
	Water chemistry variables[a]																	
Canals																		
Main	147	7.6	80	52	0.2	3.9	20.9	5.5	21.0	0.0	12.1	0.0	0.01	0.06	1.6	1.3	3.0	75
West	189	8.0	62	55	0.3	3.3	22.2	3.3	57.6	0.0	15.3	3.4	.01	0.04	1.9	1.8	11.7	126
E. Low	151	8.0	53	53	0.2	3.7	21.3	9.1	64.9	0.0	11.4	0.0	.01	0.05	2.0	1.3	3.0	84
Royal	353	8.1	76	55	0.4	4.4	22.1	7.0	93.0	0.0	18.0	5.0	.01	0.10	2.3	2.1	13.2	136
Potholes	314	8.4	127	60	1.0	4.2	24.0	16.8	143.0	2.0	39.3	10.8	.02	0.15	4.0	3.6	29.2	197
Drains																		
645	514	8.0	154	68	2.8	21.5	27.4	29.0	187.6	22.5	55.2	17.8	0.05	0.60	5.3	5.0	36.7	352
239	541	8.0	193	82	1.5	21.7	32.7	36.0	221.6	30.4	68.5	19.7	.02	0.10	6.2	5.9	37.0	273
Wasteways																		
Winchester	465	8.2	165	72	1.4	21.4	28.7	24.3	187.6	25.7	58.0	12.0	0.23	0.09	5.0	4.8	36.3	309
Frenchman	756	8.2	160	80	2.4	23.0	32.1	27.5	184.0	23.7	80.1	17.8	.04	0.29	5.5	5.5	37.7	404
Rocky Coulee	492	7.9	178	87	1.5	26.5	35.0	27.7	218.9	23.2	49.4	8.0	.02	0.23	5.4	5.0	30.7	316
Lind Coulee	428	7.7	136	71	2.1	19.7	28.4	23.1	165.9	0.0	55.7	14.5	.14	0.40	4.8	4.3	35.2	365
Esquatzel	449	8.1	152	100	3.6	41.5	40.0	24.6	175.2	1.0	44.1	20.3	.01	0.14	5.2	4.6	26.8	288
Streams																		
U. Crab	350	8.1	137	82	2.3	24.4	32.8	17.9	167.7	0.0	30.2	7.1	0.05	0.20	4.3	3.7	26.5	205
M. Crab	413	8.0	176	86	1.6	26.2	34.3	27.1	214.3	0.0	49.3	5.1	.06	0.06	5.3	4.8	30.9	264
L. Crab	760	8.1	234	92	2.0	28.2	36.8	37.5	286.1	0.0	127.7	42.3	.02	0.06	8.7	8.7	85.5	645
Rocky Ford	410	8.1	156	85	1.5	22.2	33.9	17.9	186.4	26.6	40.7	7.8	.04	0.34	4.5	4.3	25.5	270
Homestead	600	7.9	238	86	2.6	28.3	34.1	38.3	270.9	2.7	57.0	7.8	.07	0.10	6.4	6.1	34.7	346
Douglas	237	7.9	168	52	1.4	28.6	21.1	10.0	192.4	5.0	13.8	6.5	.03	2.24	2.5	2.3	14.2	148
Wilson	336	8.4	120	82	1.0	22.3	32.8	20.1	126.0	11.3	36.1	15.5	.08	0.21	4.9	3.7	34.1	221
Almira	495	8.4	167	105	2.4	23.7	42.0	19.2	264.0	4.0	45.5	31.3	.10	0.41	5.8	5.1	48.8	297

[a] All values listed are in p/m unless otherwise stated.
[b] Specific conductivity measured as μmho/cm^2.
[c] pH measured as the hydrogen ion activity in moles per liter.

Table 5.21.—*Analysis of variance for significant differences* [a] *in mean values of water chemistry between groups I, II, and III flowing waters* [b]

Chemistry[c]	Group I	Group II	Test statistic (F)	Group I	Group III	Test statistic (F)	Group II	Group III	Test statistic (F)
Spec. cond.	416.3	461.7	0.55	416.3	334.7	2.30	461.7	334.7	9.59 (**)
pH	8.0	8.0	0.02	8.0	8.1	2.11	8.0	8.1	0.98
Alkalinity	137.8	186.4	6.15 (*)	137.8	123.9	0.69	186.4	123.9	16.63 (***)
Ca hard.	72.9	85.3	2.98	72.9	76.5	0.31	85.3	76.5	1.46
NO_3	1.6	1.9	0.32	1.6	1.4	0.21	1.9	1.4	3.19
SiO_2	18.4	25.2	2.32	18.4	25.1	2.88	25.2	25.1	0.0
Ca	29.1	34.1	3.03	29.1	30.6	0.32	34.1	30.6	1.41
Mg	21.8	26.7	1.01	21.8	16.2	1.91	26.7	16.2	9.37 (**)
HCO_3	165.3	242.6	6.73 (*)	165.3	140.8	1.45	242.6	140.8	19.03 (***)
CO_3	11.6	11.4	0.0	11.6	4.8	0.56	11.4	4.8	0.46
SO_4	49.3	48.2	0.01	49.3	28.9	3.61	48.2	28.9	3.18
Cl	13.1	7.0	3.10	13.1	12.6	0.03	7.0	12.6	3.51
NO_2	0.05	0.06	0.02	0.05	0.06	0.01	0.06	0.06	0.02
PO_4	0.2	0.2	0.01	0.2	0.3	0.51	0.2	0.3	0.88
Cations	4.5	5.3	1.19	4.5	4.1	0.46	5.3	4.1	5.52 (*)
Anions	4.2	5.0	1.14	4.2	3.5	1.30	5.0	3.5	11.99 (**)
Na	29.5	29.9	0.0	29.5	27.9	0.07	29.9	27.9	0.15
TDS	294.1	299.4	0.01	294.1	204.3	1.96	299.4	204.3	7.47 (*)

[a] $p \leqslant 0.05$ (*); $p \leqslant 0.01$ (**); $p \leqslant 0.001$ (***).

[b] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is no irrigation effect.

[c] Specific conductivity measured as μmho/cm^2; pH measured in moles/L; all other values except test statistics are in p/m.

followed in decreasing numbers by Trichoptera, Coleoptera, Empheromeroptera, and Amphipoda.

Differences in abundance and diversity are probably the result of a combination of factors. Some of these factors are changes in water level, velocity, and chemistry associated with irrigation activities.

Other factors affecting invertebrate abundance and diversity in group I waters are siltation, chemical herbicides, and the presence of carp. Siltation from irrigation return flows covers aquatic plants and substrate materials to the detriment of invertebrates. Chironomids are generally the only organism taken in silted areas. Herbicide application to remove aquatic plants results in the depletion of all species of invertebrates. The type and quantity of herbicide used determines how long it takes for reestablishment to occur. The presence of carp in a stream severely impacts benthic communities. As with siltation, chironomids appear to dominate in areas where carp are present.

Fish

Flowing waters were examined for differences in fish biomass measured in both number and weight of fish per acre-foot and compared to irrigation influence and the morphometry or type of water sampled. Specifically, we wanted to know the preference of each fish species for various water types, and if the occurrence of each water type varied with irrigation influence.

Within each stream, five water types were sampled for fish and habitat features: plunge pools, pools, riffles, glides, and flats. Table 5.24 lists by group the number, acre-foot, and percent of the total area of each water type sampled. Unequal numbers of each water type were sampled because each water type did not occur in nature with equal frequency. Glides were by far the most numerous water type encountered. Group I waters accounted for most of the glides, a result of their structured channels. Riffles and pools were sampled in approximately equal numbers within each group, followed by plunge pools and flats which were the least frequently encountered water type. Plunge pools were found in greatest numbers in group I waters and are the result of drop structures to maintain a uniform channel gradient.

Differences in morphometry account for unequal area of each water type. For all groups combined,

Table 5.22.—*Benthic macroinvertebrates sampled from 20 flowing waters in the Columbia Basin, Washington*

Order Gastropoda
- Lymnaea
- Physa
- Helisoma
- Gyraulus

Order Anacylidae

Order Pelecypoda

Order Annelidae
- Oligochaeta
- Hirudinea
  - *Erpobdella*
  - *Helobdella*

Order Amphipoda
- Talitridae
- Gammaridae

Order Decapoda
- Astacidae

Order Empheromeroptera
- *Caenis*
- *Emphermerella*
- *Baetisca*
- *Epeorus*
- *Rithrogena*
- *Paraleptophlebia*
- *Isonychia*
- *Cloeon*
- *Callibaetis*
- *Baetis*
- *Tricorythodes*

Order Odonata
- Agrionidae
- Coenagrionidae

Order Plecoptera

Order Hemiptera
- Corixidae

Order Coleoptera
- Haliplidae
- Dytiscidae
- Elmidae

Order Trichoptera

Order Diptera
- Chaoborinae
- Ceratopogonidae
- Tabanidae
- Emphidinae
- Stratiomyiidae
- Sciomyzidae
- Tipulidae
- Simuliidae
- Chironimidae
  - *Chironomus*
  - *Pentaneura*
  - *Calopsectra*
  - *Rhagionidae*
  - *Ephydridae*
  - *Psychodidae*

glides accounted for 61 percent of the total area sampled. In group I, glides represented 73 percent of the total area sampled. This was expected since group I was largely composed of waters with structured channels. Pools, riffles, and flats were about equally represented for the total combined area sampled at 13.3, 9.5, and 11.8 percent, respectively. Plunge pools had the least area of any water type sampled, accounting for only 4.4 percent of the total.

Fifteen species of fish were collected during shocking operations. The number of each species of fish collected from each group of waters during electroshocking operations is listed in table 5.25. With the exception of brook trout, largemouth and smallmouth bass, the same fish species generally occur in each group. Suckers are the most abundant species in group I, carp in group II, and rainbow trout in group III.

The greatest number of fish collected came from group III, no irrigation effect, which provided 57 percent of the total. This group also had the least acreage sampled at 6.11 acre-feet. Groups I and II provided only 32 and 11 percent, respectively, of the total number of fish collected while accounting for 42.76 acre-feet or 87 percent of all flowing waters sampled. These results suggest that productivity decreases as irrigation influence increases. This is not true for all situations as at least one flowing water directly influenced by irrigation was highly productive. Numerous factors can mask a water's actual level of productivity. Differences in the amount of area sampled and age, weight, and species of fish are some of these factors. To correct for this bias, the

Table 5.23.—*Comparison of benthic invertebrates taken from groups I, II, and flowing static waters*[a] *(the data are total number of organisms collected in each taxonomic order)*

Order	Group I	II	III	All
Gastropoda	209	82	96	387
Anacylidae		6	11	17
Pelecypoda		4	26	30
Annelidae	373	62	32	467
Amphipoda	699	286	138	1,133
Decapoda			84	84
Empheromeroptera	220	734	439	1,393
Odonata	37	6	28	71
Plecoptera			6	6
Hemiptera	15	5	132	152
Coleoptera	404	190	880	1,474
Diptera	3,028	1,399	1 268	5 695
Total no organisms	5,098	3,309	4,004	12,411
Total no. samples	632	167	120	919
Average no /sample	8.1	19.8	33 3	13.6

[a] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is no irrigation effect.

Table 5.24.—*The number and acre feet of each water type in groups*[a] *I, II, and III flowing waters electroshocked for fish during 1978, Columbia Basin, Washington*

Water type	Group I No. sites	I Acre-ft	I (percent)	II No. sites	II Acre-ft	II (percent)	III No. sites	III Acre-ft	III (percent)	All No. sites	All Acre-ft	All (percent)
Plunge pool	17	2.10	6.2			—	2	0.06	1.0	19	2.16	4.4
Pool	21	1.70	5.0	16	3.03	33.6	26	1.75	28.6	63	6.48	13.3
Riffle	26	3.18	9.4	15	0.95	10.5	26	0.51	8.3	67	4.64	9.5
Glide	88	24.69	73.1	24	3.45	38.2	20	1.69	27.7	132	29.83	61.0
Flat	5	2.09	6.3	5	1 60	17.7	6	2.10	34.4	26	5.79	11.8
Totals	158	33.76	69.0	60	9.03	15.5	80	6.11	12.5	297	48.90	100.0

[a] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is no irrigation effect.

data were examined both in numbers and weight of fish by species and standardized to an acre-foot for each water type sampled. Of principal concern were the game fish species.

Trout abundance was considerably greater in water with no irrigation influence. This is shown in figure 5.6 in which 94 percent of the number and 76 percent of the weight of all trout sampled came from group III waters. Groups I and II had fewer trout in both numbers and weight than group III but were about equal with each other. Natural reproduction of trout has been observed in a few waters of groups I and II. However, most trout collected from these waters originated from WDG stocking operations or were introduced through the irrigation water delivery system. The majority of trout in group III waters originated from natural reproduction.

Table 5.25.—*The number of each fish species captured during electrofishing surveys of groups [a] I, II, and III flowing waters in 1978, Columbia Basin, Washington*

Species	Group I	Group II	Group III	Total number
Rainbow trout	72	64	1,532	1,670
Brown trout	27	50	72	140
Brook trout		8		8
Largemouth bass	63			63
Smallmouth bass	1			1
Yellow perch	61	4	3	68
Black crappie	11	210	9	230
Pumpkinseed sunfish	113	8	3	124
Bluegill	13	1	3	17
Sucker sp.	1,364	158	1,526	3,048
Carp	269	256	160	685
Sculpin	394	71	201	666
Brown bullhead	26	2	15	43
Squawfish		1	47	48
Redside shiner	4		769	773
Total number	2,418	833	4,342	7,593

[a] Group I is direct irrigation effect; group II is indirect irrigation effect; group III is no irrigation effect.

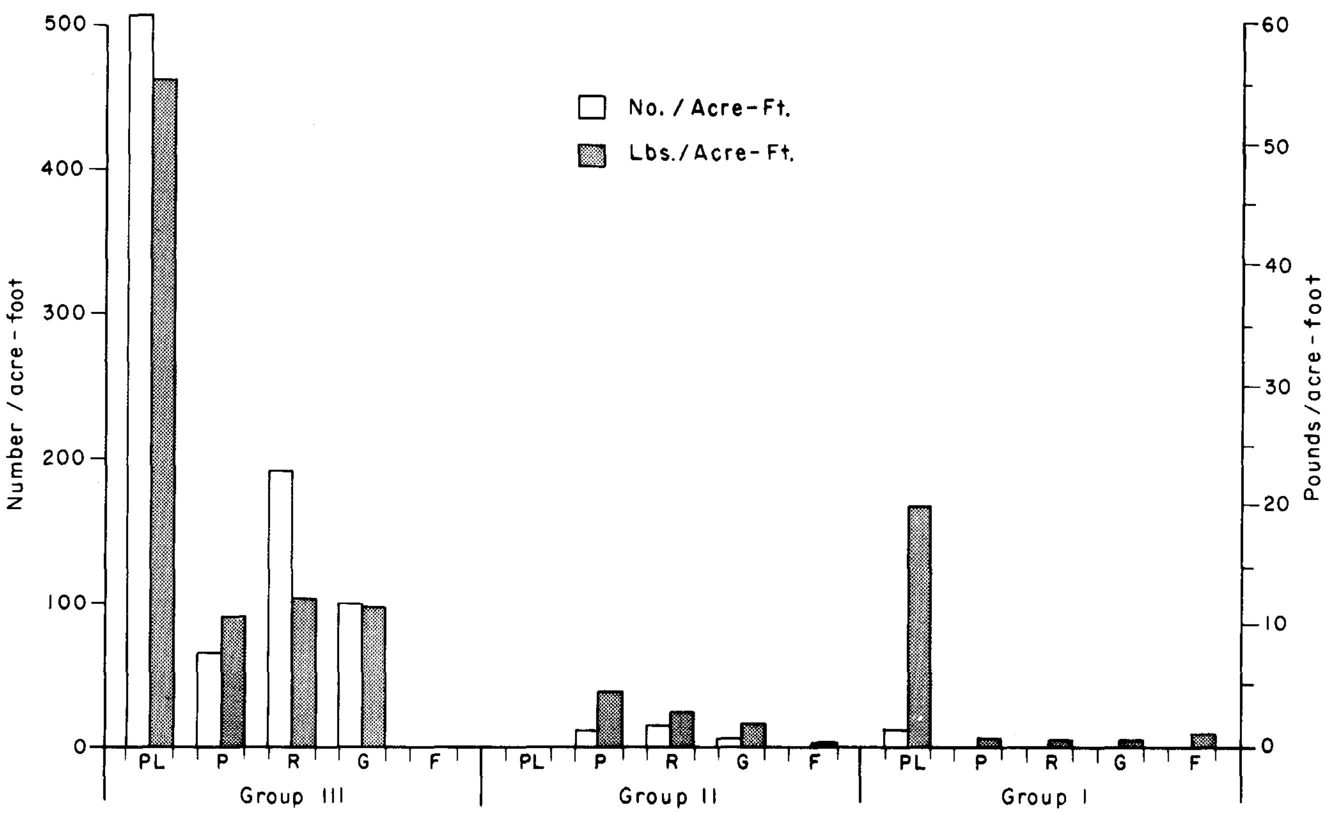


Figure 5.6.–The average number and weight of trout captured in each water type of group III, II, and I flowing waters in the Columbia Basin, Washington, during 1978. Group III waters are not affected by irrigation, group II are indirectly affected by irrigation, and group I waters are directly affected by irrigation. PL = plunge pool; P = pool; R = riffle; G = glide; F = flat.

The occurrence of fish other than trout in each water type is shown in figure 5.7. Large numbers of suckers and redside shiner accounted for the high density of fish shown in group III. The corresponding biomass was low because of the small size of these fish. Fewer fish per acre-foot occupied group I and II waters, but their average weight was greater. This difference in weight of fish from group I is partially due to recruitment of large carp and suckers from storage reservoirs. Adult carp were taken at numerous sites from group II waters and account for much of the biomass. Because of the low numbers taken during sampling, spiny-ray game fish are included with fish other than trout in this discussion. Yellow perch and crappie occurred in all groups but the greatest diversity of spiny-ray fish occurred in group I. This was expected since these waters are directly connected to reservoirs containing many fish species.

These results indicate the preference of fish for certain water types. That is to say, they occurred in greater numbers and biomass in specific types of water. A review of figure 5.6 shows the greatest concentration of trout were found in plunge pools regardless of irrigation influence. Other water types containing less trout but comparable to each other were pools, riffles, and glides. Trout utilized flats less than any other water type. Similar preferences in water type were exhibited by fish other than trout as shown in figure 5.7. A better illustration of the occurrence of fish by water type is shown in figure 5.8. The data were pooled to eliminate irrigation effect and examined individually as trout, other, and all fish. The greatest biomass of fish regardless of species is found in plunge pools followed in decreasing order by pools, riffles, glides, and flats. When the data are separated into trout and other species, the same general trend exists.

Plunge pools provide prime instream cover, resting, and feeding stations for many fish species. They are natural collection and mixing areas for food items drifting with the current. Visibility is relatively good but limited somewhat by water turbulence. Fish can actively forage most places within a plunge pool without being observed from above. Pools, especially those deeper than 3 feet, offer similar advantages except visibility is greater both within and from above. Added cover features such as undercut banks, overhanging vegetation, and aquatic plants make pools a favored area for fish habitation.

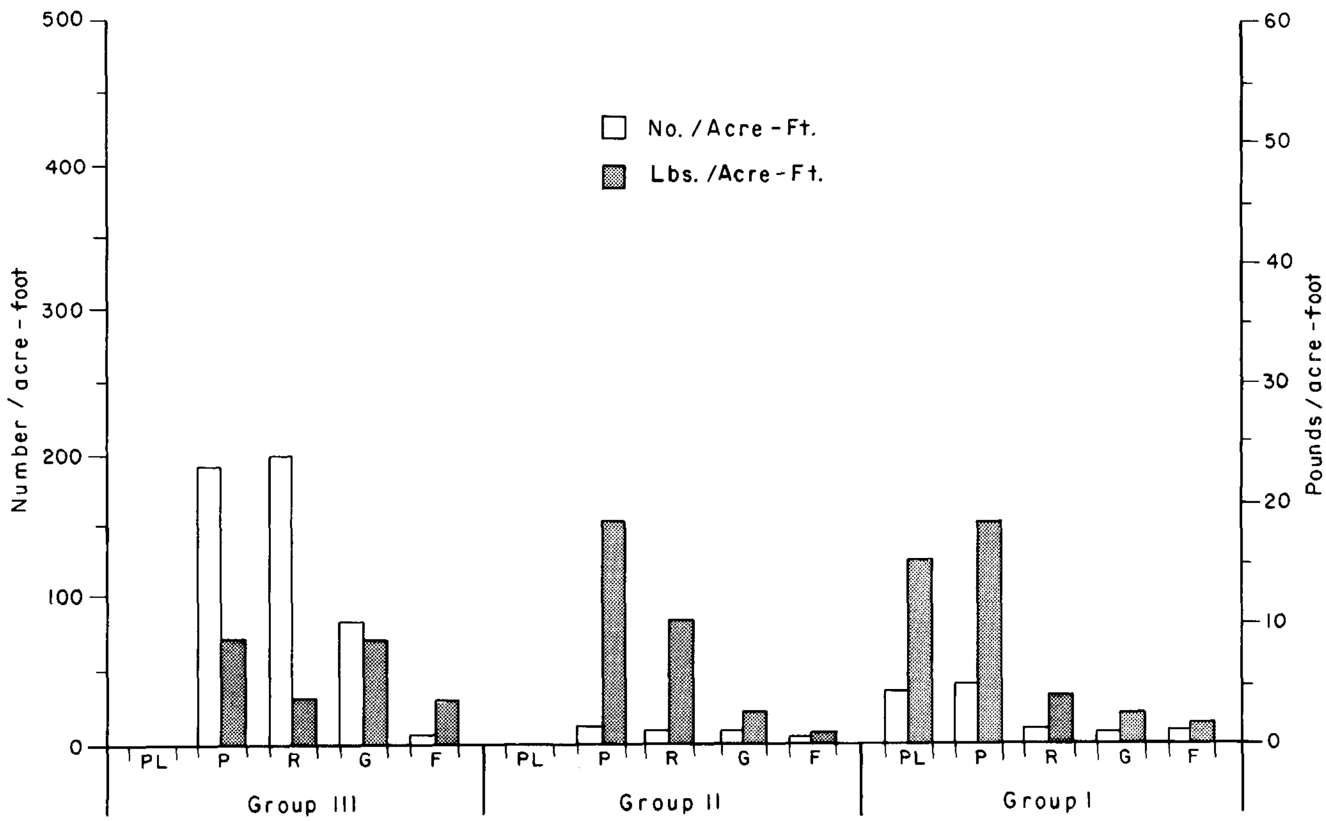


Figure 5.7.–The average number and weight of fish other than trout captured in each water type of groups III, II, and I flowing waters in the Columbia Basin, Washington, during 1978. Group III waters are not affected by irrigation, group II are indirectly affected by irrigation, and group I waters are directly affected by irrigation. PL = plunge pool; P = pool; R = riffle; G = glide; F = flat.

Riffles function as a nursery for juvenile fish of many species. Cover in the form of a broken water surface and rock crevices and an abundant food supply make riffles an ideal refuge for small fish. This is evident by the large numbers of fish per acre-foot found in this water type. Glides and flats had the least number and biomass of fish sampled. These water types usually have smooth channels consisting of fine gravel, sand, or silt, and without a border of overhanging vegetation or undercut banks they provide minimal cover.

Cover is one of the most important aspects of aquatic habitat contributing to fish production. Many features providing cover were quantified along with chemistry, morphometry, and the presence or absence of specific macroinvertebrates. The contribution of these independent variables to changes in fish biomass is discussed in the following section.

Modeling of Variables

Using stepwise linear regression analysis, numerous environmental variables were examined for correlation with fish abundance. These variables were length, width, and minimum and maximum depth of the sample site, water and substrate color, substrate size, percentage of bank area with undercuts greater than 6 inches, percentage of bank area showing signs of erosion, percentage of bank area with overhanging vegetation, water type, type of aquatic vegetation, percentage of stream bottom covered by aquatic vegetation, type of riparian vegetation, type of bank cover, water temperature, dissolved oxygen and pH, and numerous water chemistry variables. Because of equipment malfunctions and lengthy repair time, stream flows, velocity, and discharge were not included in the analysis.

Highly correlated variables were used to develop mathematical models to predict fish biomass in flowing waters. Separate models were constructed for each fish species in each group of waters. An independent variable was added to the model if it could contribute more to the model coefficient of determination (r^2) than could any other independent variable not already included. Two types of significance levels or p-values were associated with each model. The model p-value indicated statistical significance of the existing model but each independent variable had its own p-value as well. In many cases, then, the overall predictive ability of a model may be improved by adding independent variables, but the variables added may not each be very credible. Because of this, most of these variables can by themselves, be considered predictors of fish biomass. Under these

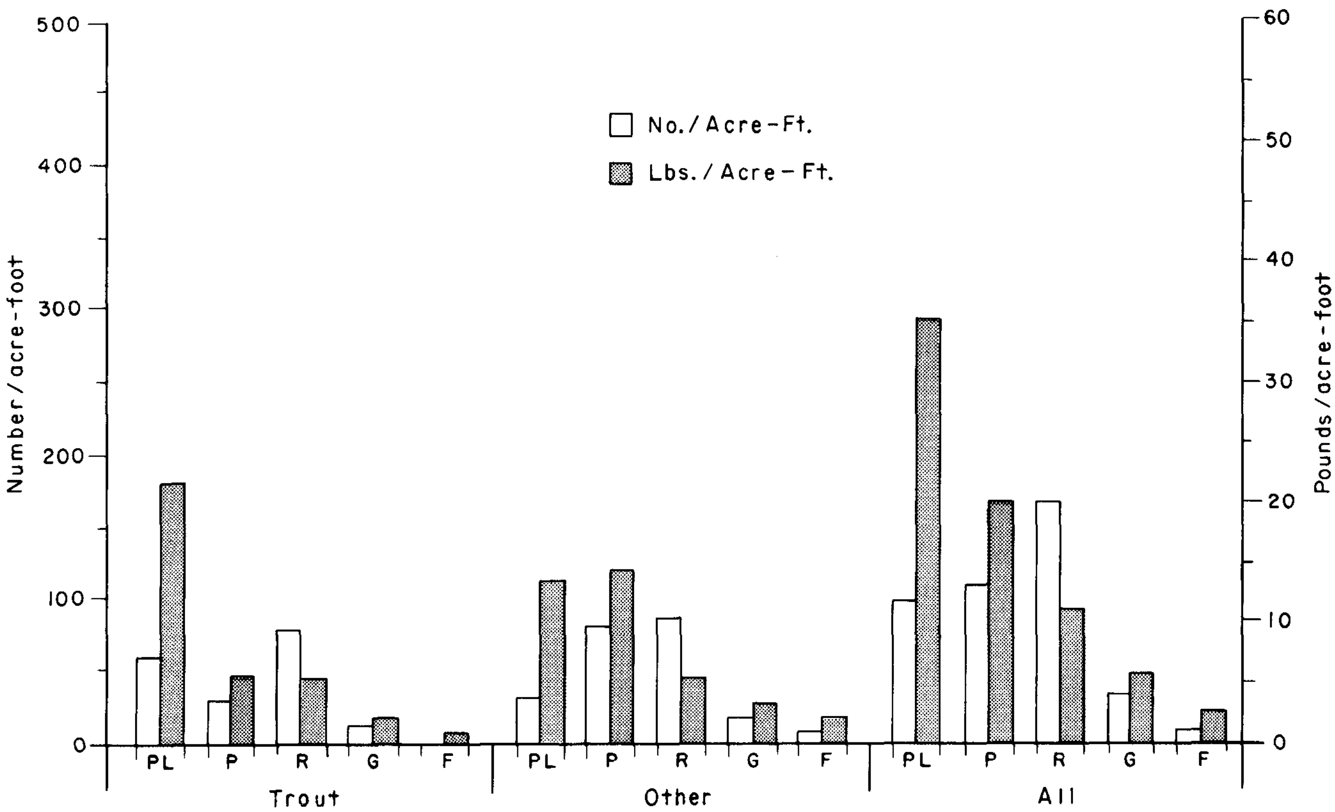


Figure 5.8.–The average number and weight of all fish species captured in each water type of group I, II, and III flowing waters in the Columbia Basin, Washington, during 1978. PL = plunge pool; P = pool; R = riffle; G = glide; F = flat.

considerations, models were also constructed for pooled variables such as total fish biomass by fish family or for all groups of irrigation influence combined. Independent variables of interest are separated into three classes. Class I variables are those which are significant at the $p \leq 0.05$ level, given that the model itself is also significant at the $p \leq 0.05$ level. Here we are 95 percent sure that the overall model is real, not just a chance occurrence in the data and are similarly confident that each variable belongs in the model. Class II variables are those in which when entered, we have less than 95 percent confidence, but the overall model is still significant at the $p \leq 0.05$ level. Class III variables are those which because of mutual correlations, could be substituted for either class I or class II variables without appreciably changing the significance level of the model. In no model has regression degrees of freedom been allowed to exceed error degrees of freedom. The dependent variable for each model is standing crop of fish biomass (g/acre-ft).

Two important features of this kind of model are the ability to predict fish biomass with a known degree of confidence, and the ability to identify the variables accounting for variation in fish biomass. With each model, the coefficient of determination (r^2) shows the amount of variation in fish biomass that can be accounted for or replaced by variation in the correlated variables. Hence, the variables in a model with an $r^2=0.70$ explain 70 percent of the variation of fish biomass.

Table 5.26 lists three linear models developed for rainbow trout exclusively with class I variables. In group I waters, direct irrigation effect, four variables explain 80 percent of the variation in rainbow trout standing crop. These variables are chloride ion concentration, substrate color, water type, and riparian vegetation. Two variables explain 70 percent of the variation in rainbow trout biomass for group II waters, indirect irrigation effect. They are calcium ion concentration and overhanging vegetation. In group III waters, no irrigation effect, six variables account for 50 percent of the variation in rainbow trout biomass. These variables are calcium hardness, stream width, substrate color, water type, bank cover, and alkalinity.

Table 5.27 lists three linear models developed for brown trout using class I variables. For group I waters, direct irrigation effect, two variables explain 99 percent of the variation in brown trout biomass. These variables are water type and water temperature. In group II waters, indirect irrigation effect, six variables explain 96 percent of the variation in brown trout biomass. These variables are silicon dioxide concentration, stream length, maximum depth, bank stability, water type, and alkalinity. For group III waters, no irrigation effect, two variables explain 72 percent of the variation in brown trout biomass. They are substrate type and water type.

Data on both rainbow and brown trout were combined to develop three linear models for trout in flowing waters. These models are listed in table 5.28. In group I waters, four variables explain 74 percent of the variation in trout standing crop. These variables are width of stream, bank stability, bank cover, and alkalinity. Nine variables explain 69 percent of the variation in trout biomass from group II waters. They are chloride ion concentration, length of stream section sampled, mean water depth, maximum water depth, substrate color, percentage of undercut banks, overhanging vegetation, alkalinity, and water temperature. In group III waters, six variables account for 74 percent of the variation in trout biomass. These variables are sodium ion concentration, substrate color, water type, percent of substrate covered by aquatic vegetation, type of riparian vegetaion, and length of stream section sampled.

The nine models just presented display considerable variation. No two models are the same, although certain variables occur more frequently indicating their importance to trout standing crop. The most significant variable is water type, which occurs in six of the nine models. Color of the bottom or substrate occurs four times and alkalinity and length of stream section sampled each occur three times. With the exception of stream length, these variables constitute what is commonly termed important habitat features. Individually or together, through some synergistic effect, they influence trout standing crop in most of the flowing waters studied.

Because of an oversight during data coding, measurements of stream length, width, and depth were included in the regression analysis. These same measurements were used to calculate standing crop (g/acre-feet). Their inclusion as independent variables results in a biased model.

Only one model was developed for spiny-ray game fish using class I variables. The game fish species are yellow perch, largemouth and smallmouth bass, and crappie. Table 5.29 lists the three variables which explain 70 percent of the variation in fish biomass. They are stream width, maximum water depth, and water type. The biomass of all other fish species such as carp, suckers, cottids, etc., in group I waters correlate significantly with four variables explaining 67 percent of the variation in standing crop. The variables listed in table 5.29 are magnesium ion concentration, stream width, percentage of undercut banks, and bank stability.

These models are expressed mathematically using the B-values determined by analysis of variance. As an example, for group I waters, direct irrigation

Table 5.26.—*Analysis of variance of independent variables*[a] *regressed against standing crop (g/acre-ft) of rainbow trout in flowing waters of the Columbia Basin, Washington*

Direct Irrigation Effect

Best four-variable model $r^2 = 0.798$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	4	18880292523.28	4720073130.82	10.92	0.0008
Error	11	4754093329.73	432190302.70		
Total	15	23634385853.01			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	124509.69				
Cl	1413.13	536.26	3001155884.21	6.94	0.0232
Colorbtm	–31529.30	9694.81	4571141413.75	10.58	.0077
Watertyp	29469.47	5413.47	12807581329.06	29.63	.0002
Ripvegi	–41452.88	13111.13	4320197619.27	10.00	.0091

Indirect Irrigation Effect

Best two-variable model $r^2 = 0.703$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	2	265549442.42	132774721.21	7.12	0.0261
Error	6	111909206.98	18651534.49		
Total	8	377458649.40			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–57438.87				
Ca	16662.74	5739.71	157190995.91	8.43	0.0272
Overveg	2212.37	849.01	126648200.01	6.79	.0403

No Irrigation Effect

Best six-variable model $r^2 = 0.498$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	6	78614635539.44	13102439256.57	7.12	0.0001
Error	43	79085069609.93	1839187665.34		
Total	49	157699705149.38			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	161858.61				
Cah	–2013.61	626.81	18980149853.45	10.32	0.0025
Width	–4981.36	1124.21	36109859819.39	19.63	.0001
Colorbtm	46306.43	14968.91	17600615142.05	9.57	.0035
Watertyp	22496.81	8357.95	13325033448.81	7.25	.0101
Bankcvr	24455.34	8847.69	14051187296.96	7.64	.0084
Ph2	–13443.95	4258.24	19224740048.79	10.45	.0024

[a] See appendix H for explanation of abbreviations and terms.

Table 5.27.—*Analysis of variance of independent variables*[a] *regressed against standing crop (g/acre-ft) of rainbow trout in flowing waters of the Columbia Basin, Washington*

Direct Irrigation Effect

Best two-variable model $r^2 = 0.992$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	2	9564379814.87	4782189907.43	382.19	0.001
Error	6	75074842.74	12512473.79		
Total	8	9639454657.61			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	134280.64				
Watertyp	55369.20	2023.26	9370780178.27	748.92	0.0001
Temperat	– 3872.06	393.03	1214422053.95	97.07	.0001

Indirect Irrigation Effect

Best six-variable model $r^2 = 0.955$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	6	552296771.89	92049461.98	43.37	0.0001
Error	12	25468385.24	2122365.43		
Total	18	577765157.13			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–13759.92				
SiO_2	1581.60	176.34	170725244.55	80.44	0.0001
Length	–29.96	6.06	51845594.55	24.43	.0003
Mxdepth	–5293.61	592.85	169212527.55	79.73	.0001
Stabilit	–209.78	29.67	106088486.03	49.99	.0001
Watertyp	1520.06	440.36	25288156.86	11.92	.0048
Ph2	909.72	165.60	64048922.63	30.18	.0001

No Irrigation Effect

Best two-variable model $r^2 = 0.721$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	2	2248323389.37	1124161694.68	9.06	0.0114
Error	7	868458292.62	124065470.37		
Total	9	3116781682.00			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	17316.03				
Substri	–11234.12	2706.35	2137767542.48	17.23	0.0043
Watertyp	21845.07	8146.62	892077035.34	7.19	.0315

[a] See appendix H for explanation of abbreviations and terms.

Table 5.28.—*Analysis of variance of independent variables*[a] *regressed against standing crop (g/acre-ft) of rainbow and brown trout in flowing waters of the Columbia Basin, Washington*

Direct Irrigation Effect

Best four-variable model — $r^2 = 0.738$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	4	6376796.15	1594199.03	14.84	0.0001
Error	21	2255554.92	107407.37		
Total	25	8632351.07			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–6426.61				
Width	38.41	5.06	6178457.32	57.52	0.0001
Stabilit	14.29	3.38	1920898.22	17.88	.0004
Bankcvr	654.68	189.95	1275894.84	11.88	.0024
Ph2	289.16	91.03	1083826.76	10.09	.0046

Indirect Irrigation Effect

Best nine-variable model — $r^2 = 0.689$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	9	24750.15	2750.01	2.72	0.0606
Error	11	11135.39	1012.30		
Total	20	35885.54			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	445.83				
Cl	–35.61	9.64	13817.42	13.65	0.0035
Length	0.24	0.12	3610.08	3.57	.0856
Mndepth	16.36	10.35	2531.08	2.50	.1421
Mxdepth	17.62	12.81	1915.27	1.89	.1963
Colorbtm	–33.99	18.01	3603.36	3.56	.0859
Undercut	1.02	0.50	4201.18	4.15	.0664
Overveg	14.85	5.78	6699.89	6.62	.0259
Ph2	15.90	5.83	7527.05	7.44	.0197
Temperat	–5.52	2.34	5646.69	5.58	.0377

No Irrigation Effect

Best six-variable model — $r^2 = 0.728$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	6	2781152.13	463525.35	19.65	0.0001
Error	44	1037965.54	23590.12		
Total	50	3819117.67			

Table 5.28.—*Analysis of variance of independent variables*[a] *regressed against standing crop (g/acre-ft) of rainbow and brown trout in flowing waters of the Columbia Basin, Washington*—Continued

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–546.60				
Na	–6.77	3.32	97670.47	4.14	0.0479
Length	4.16	0.50	1582893.54	67.10	.0001
Colorbtm	138.97	56.43	143051.88	6.06	.0178
Watertyp	68.52	25.26	173491.11	7.35	.0095
Percenti	–1.80	0.71	151618.67	6.43	.0149
Ripvegi	41.87	17.74	131365.49	5.57	.0228

[a] See appendix H for explanation of abbreviations and terms.

Table 5.29.—*Analysis of variance of independent variables*[a] *regressed against standing crop (g/acre-ft) of spiny-ray and nongame fish species in flowing waters of the Columbia Basin, Washington*

Direct Irrigation Effect

Best three-variable model $r^2 = 0.703$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	3	77402.78	25800.92	13.43	0.0001
Error	17	32659.74	1921.16		
Total	20	110062.52			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–7.94				
Width	1.83	0.68	13715.87	7.14	0.0161
Mxdepth	–56.34	9.41	68832.02	35.83	.0001
Watertyp	70.81	14.49	45867.75	23.88	.0001

NONGAME FISH

Direct Irrigation Effect

Best four-variable model $r^2 = 0.668$

Model	DF	Sum of squares	Mean squares	F	PROB>F
Regression	4	36994420.40	9248605.10	19.66	0.0001
Error	39	18350882.11	470535.43		
Total	43	55345302.52			

Variable	B value	Standard error	Type II SS	F	PROB>F
Intercept	–549.24				
Mg	–54.13	17.15	4687612.62	9.96	0.0031
Width	46.64	8.18	15292779.39	32.50	.0001
Undercut	29.58	6.42	9979415.33	21.21	.0001
Stabilit	14.21	4.10	5641864.06	11.99	.0013

[a] See appendix H for explanation of abbreviations and terms.

effect, the best four variable model for rainbow trout is expressed as follows:

Biomass (g/acre-ft) = 124510+1413 (chloride ion) − 31529 (color of bottom)+29469 (water type) − 41453 (riparian vegetation).

The addition of class II variables increased the number of models to 33, one for each fish species and group of waters. This also increased r^2 our index to the amount of variation explained by the model. However, a previous definition of class II variables states that we are less than 95 percent confident that these particular variables are really influencing biomass levels. In fact, the class III variables are sufficiently correlated with some of those in classes I and II that substitutions may be made without dramatically changing either the confidence level or the coefficient of determination for the model. This occurs because all measured variables show some degree of correlation although we may deem the relationship insignificant or due entirely to chance. As such, the additional models are not included for discussion.

The models we have discussed are of the simple linear additive type. They are built primarily with independent variables measured on a linear scale. For example, biomass may increase as the percentage of undercut bank increases and vice versa. The inclusion of each new variable adds to or subtracts from the response of all existing variables. The resulting change in fish biomass is linear. However, growth response is a nonlinear function and by using linear models we may be missing the effect of certain variables on fish biomass. Establishing a simple linear relationship between the variables is the first step in modeling. This is followed by an analysis of interaction effects in which the variables are examined for nonlinear relationships and eventually lead to more complex models. Because of time and financing, we did not proceed past simple linear modeling.

WATER LEVEL FLUCTUATIONS

Concern over the loss of aquatic habitat as a result of receding ground-water levels motivated a survey of lake levels in the Desert Wildlife Recreation Area of Grant County, Washington. The objective of the survey was to monitor annual fluctuations of lake levels in order to determine if a downward trend was in evidence. Of particular interest were those lakes proximal to center-pivot irrigation wells, a feature suspected of contributing to the lowering of the water table and, consequently, lake levels.

Methods and Materials

A steel gage, graduated in 0.1 ft. and secured to a metal stake, was placed in eight sites selected for study. The stake was driven into the substrate until the water level on the gage read plus 1.00 ft. This allowed measurements of both positive and negative changes in lake levels. Where water levels rose above or dropped below the gage, a metal pocket tape, graduated in 0.01 ft., was used as an extension to obtain the measurement.

Additional data collected from each lake on monitoring days included alkalinity, dissolved oxygen, and temperature of surface water. Alkalinity was measured with a Taylor Color Slide Comparator. Dissolved oxygen was determined from 60-mL samples using a Hach kit and powder pillows. All lakes were measured on the same day, usually the middle of each month. During the height of the irrigation season, measurements were recorded twice monthly. Information on precipitation, evaporation, ground-water levels, and acreage irrigated was obtained from the USBR, Ephrata, Washington.

Results and Discussion

The study area encompassing the lakes measured for declining water levels is illustrated in figure 5.9. Lands within the sand-dune area constitute the Quincy ground-water subarea. Within this area lies the region known as the Black Sands. Both Winchester and Frenchman Hills Wasteways pass through the Black Sands on their route to Potholes Reservoir.

Mean monthly lake levels are illustrated in fig. 5.10 for the period January 1975 to November 1979, a total of 1,784 days. The data show the lowest lake levels occur in August and the highest during January. A comparison of the months of August show a definite decrease in the level of each lake examined. This was determined using simple linear regression of the form $y = a + bx$ with lake level (y) regressed on time (x) in days. These results are listed in table 5.30 as the negative slope of the regression equations and represent the decrease in feet per day of lake level. To put these values in perspective, table 5.30 lists the time in years it will take the level of each lake to drop 2 feet below their August 1975 level. Four possible causes of declining lake levels are: (1) changing weather patterns resulting in increased evaporation of surface waters; (2) receding water table levels as a result of ground-water pumping and/or reduced wasteway flow; (3) increasing emergent vegetation; and (4) a combination of the above factors.

Weather

Climatic conditions of the Columbia Basin result in the least precipitation and highest evaporation rates

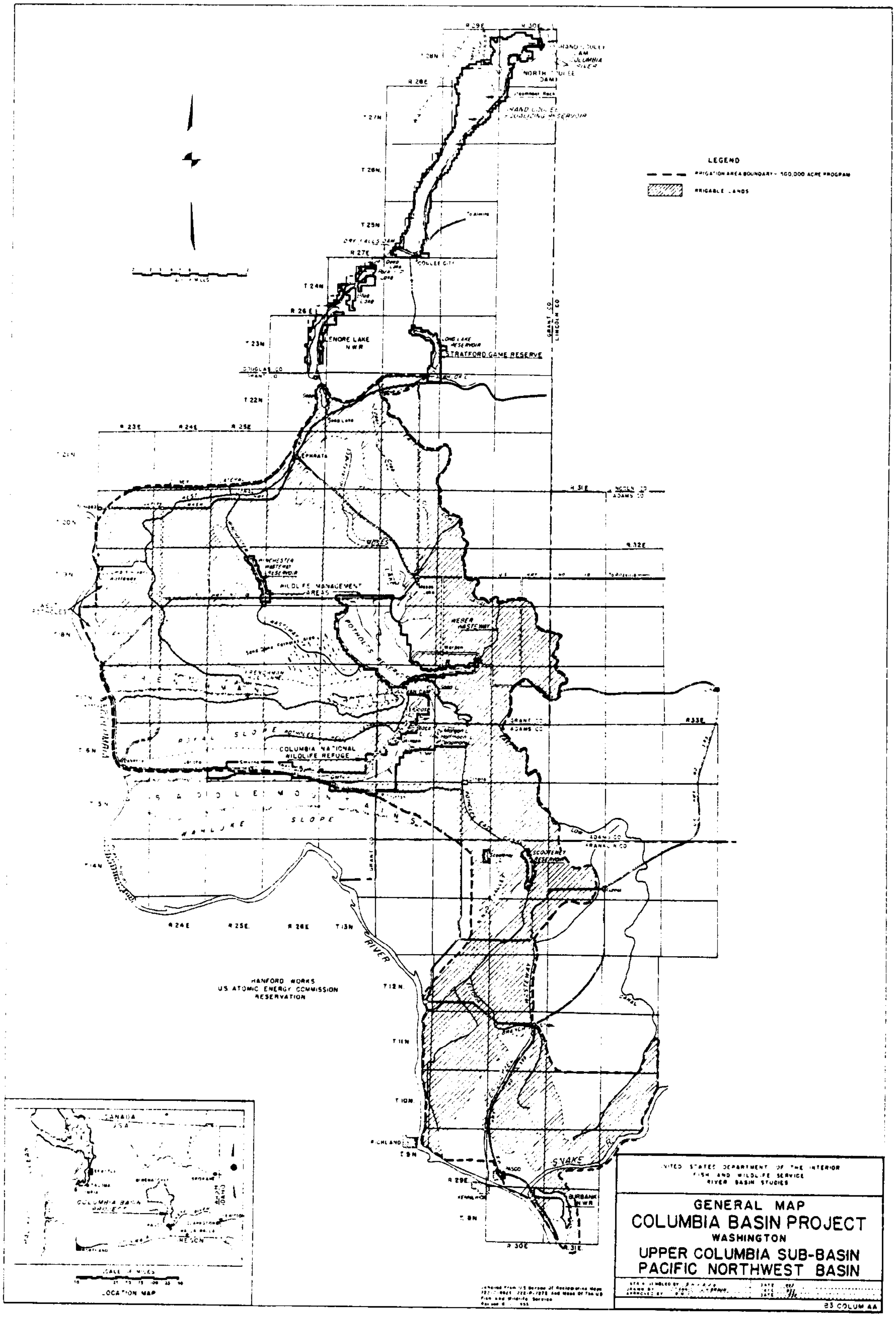


Figure 5.9.–Map of the Columbia Basin Irrigation Project. The area labeled Sand Dune Potholes area is also referred to as the Black Sands.

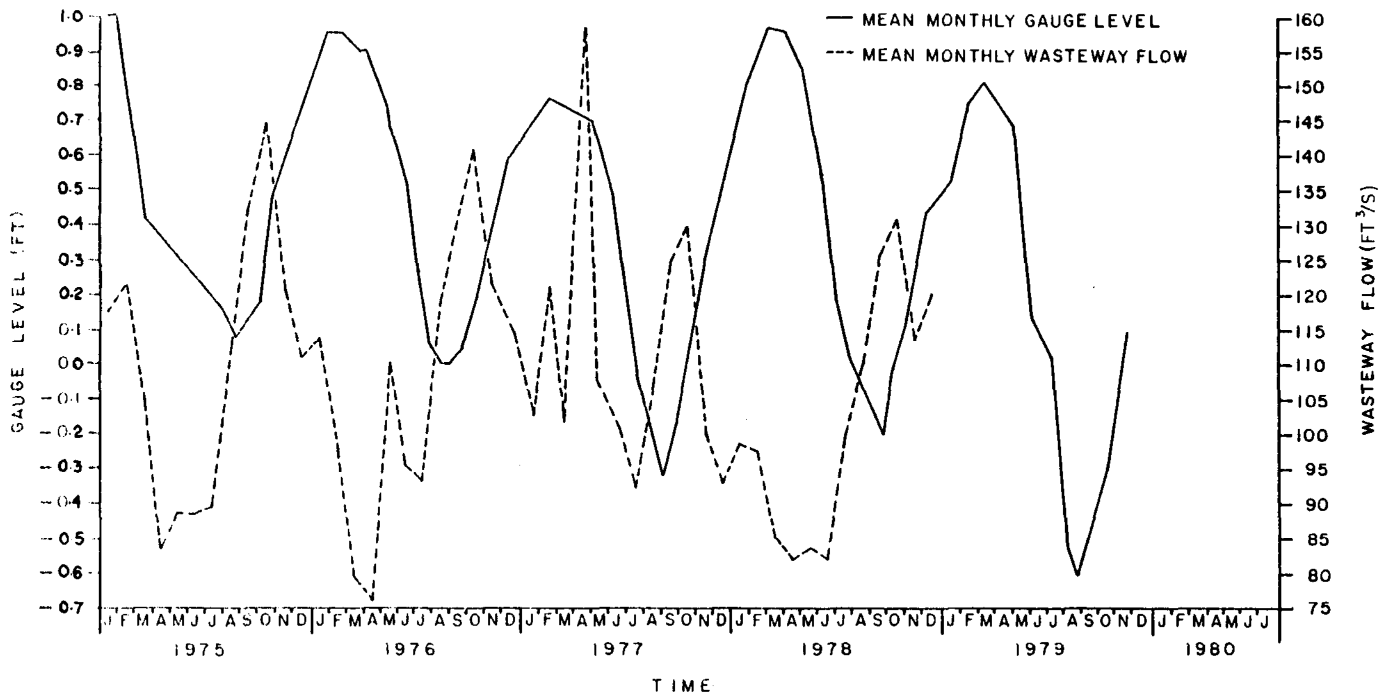


Figure 5.10.–Mean monthly changes in lake level of seven seep lakes and flow of Winchester Wasteway from January 1975, until November 1979 in the Desert Habitat Management Area, Grant County, Washington.

Table 5.30.–*Linear regression of the form y = a + bx for lake level (y) on time in days (x) of seven seep lakes in the Desert Habitat Management Area, Grant County, Washington*

Location	Correlation coefficient (r^2)	Intercept (a)	Feet/day (b)	Years to drop 2 ft	Date
Beda	0.89	1.83	–0.000608	10.01	08/23/85
Brookie	.51	2.36	–.000223	26.58	03/14/02
March	.35	2.59	–.000149	38.45	01/21/14
Lizard	.48	2.28	–.000322	17.30	12/05/92
Dune	.68	1.94	–.000289	19.53	02/24/95
Harris	.92	2.02	–.000790	7.79	06/03/83
Desert	.89	2.12	–.000416	14.23	11/09/89

anywhere in the State of Washington. Although precipitation is not considered a significant factor affecting lake levels in this area, it was examined for changing trends during the past 20 years.

Annual precipitation for the study area is illustrated in figure 5.11 for the years 1959 through 1978. The mean annual precipitation for this period was 6.8 inches with a low of 2.9 and a high of 12.5 inches. During the study period, 1975 to 1979, the average annual precipitation was 6.3 inches, only 0.5 inch below the 20-year mean. These small changes in annual precipitation are relatively undramatic from the standpoint of their effect upon lake levels.

Considering the lack of precipitation, lake levels could be affected by loss of water to evaporation. The annual loss of water by evaporation from lakes in eastern Washington ranges from 28 to 62 inches. Annual evaporation is estimated at 60 inches for the study area (Washington Climate 1979) [11]. Figure 5.12 illustrates the annual evaporation of water at a station located 15 miles from the lakes. Measurements are in inches for the months of April through October of each year. These are the driest months which also mark the start and finish of the irrigation season. The mean annual evaporation for the past 20 years at this station was 51.24 inches with a low and high of 40.53 and 57.73 inches, respectively. During the 5-year study period, the mean annual

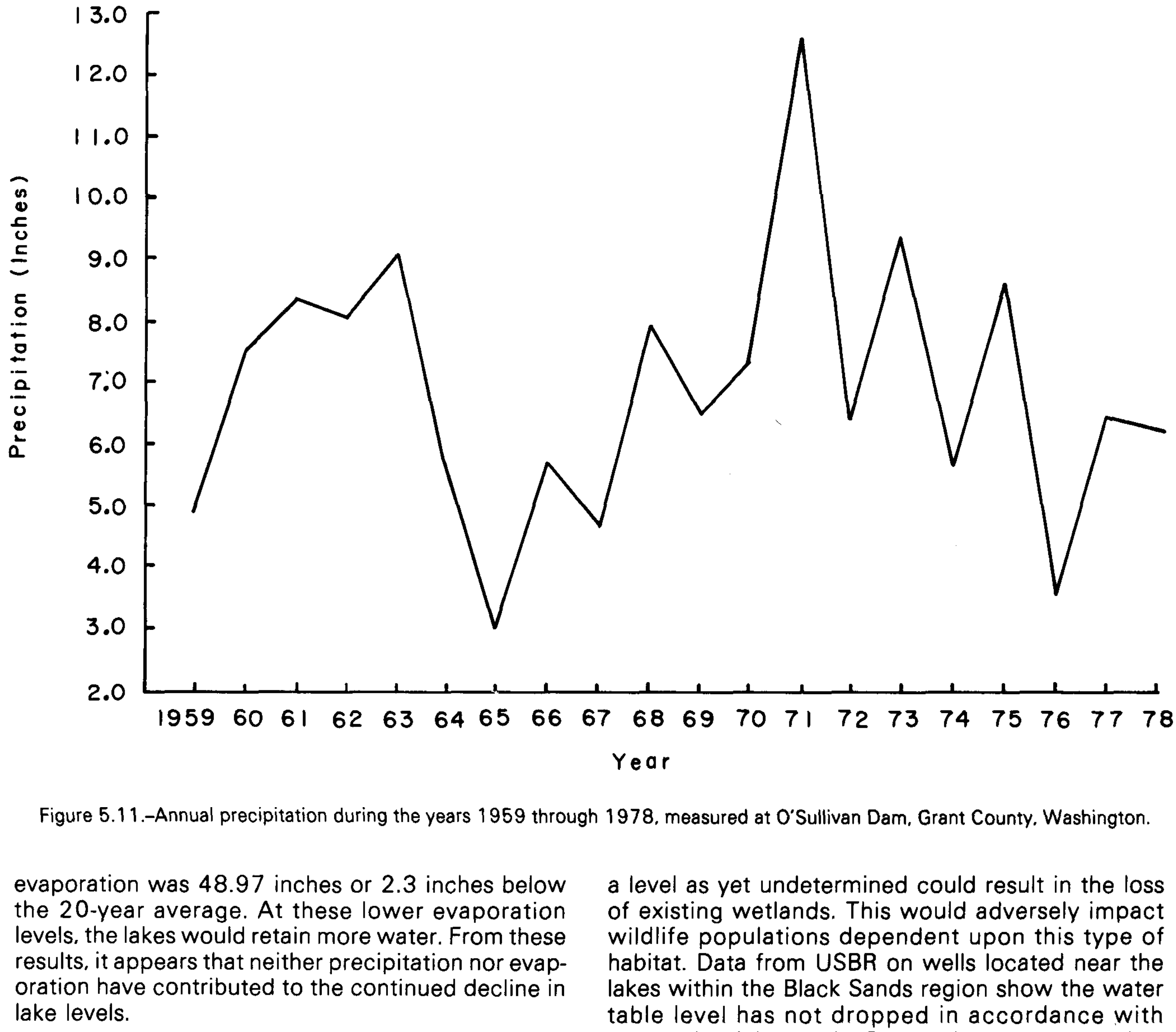


Figure 5.11.–Annual precipitation during the years 1959 through 1978, measured at O'Sullivan Dam, Grant County, Washington.

evaporation was 48.97 inches or 2.3 inches below the 20-year average. At these lower evaporation levels, the lakes would retain more water. From these results, it appears that neither precipitation nor evaporation have contributed to the continued decline in lake levels.

Ground Water Withdrawal

In the original land-use design of the Columbia Basin Project, class 6 and other lands considered marginal for growing crops were excluded from irrigation development. An area within the Quincy groundwater subarea, known as the Black Sands region, was among these deferred and by-passed lands. The soil of the Black Sands region was considered too sandy for farming potential of this region, but with the advent of center-pivot irrigation, this area experienced rapid agricultural development. Figure 5.13 shows the area irrigated by ground water has steadily increased from zero in 1966 to 24,142 acres in 1978.

Increasing use of ground water within the Black Sands region has raised concerns about receding water table levels. A drop in the water table below a level as yet undetermined could result in the loss of existing wetlands. This would adversely impact wildlife populations dependent upon this type of habitat. Data from USBR on wells located near the lakes within the Black Sands region show the water table level has not dropped in accordance with decreasing lake levels. Rather, it has continued to increase at a steady rate. The mean water level in three wells located within a 5-mile radius of the lakes has risen between 3.2 and 6.4 ft. during the study. However, this area is relatively undeveloped compared to acreage further north where ground water removal is greatest. Here, the water table has moderated in recent years and a number of wells are decreasing in level as shown in figure 5.14. Hydrologists with USBR believe this to be the initial sign of pumping stress, indicating ground water removal within the immediate area has reached its peak.

These results indicate that surface waters are not directly affected by a fluctuating water table. This suggests that surface waters are fed from another source. The only sources of water available are Winchester and Frenchman Hills Wasteways which flow through the Black Sands region. Winchester Wasteway flows nearest the lakes studied.

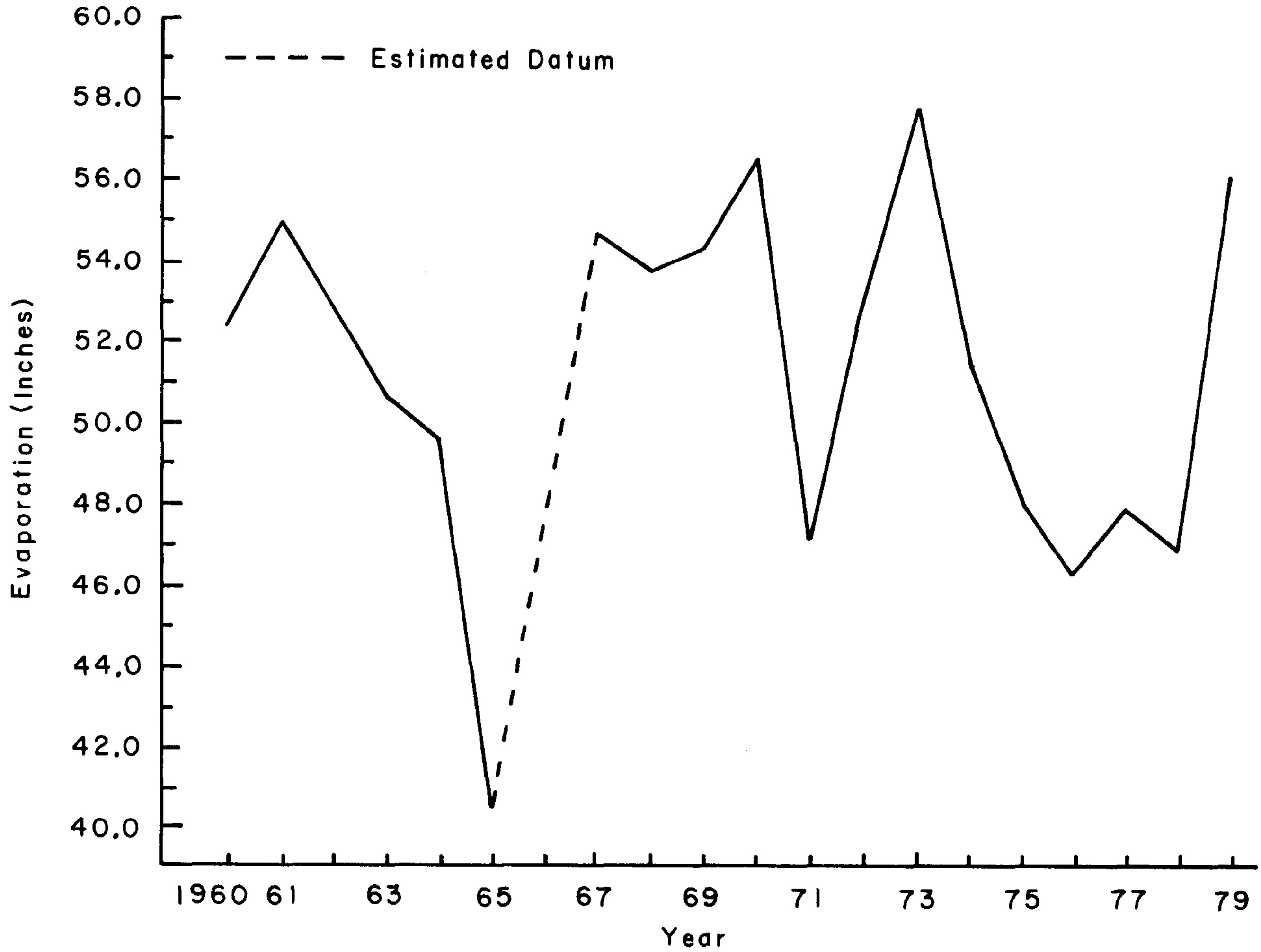


Figure 5.12.–Annual evaporation of water at O'Sullivan Dam, Grant County, Washington. Data are for the months of April through October of each year from 1960 to 1979. No data were collected during 1966.

Wasteway Flows

Winchester Wasteway originates as a concrete bifurcation of West Canal 7 miles east of Quincy, Washington. The channelized upper third of the wasteway collects irrigation return flows which are conveyed to Potholes Reservoir. The wasteway is approximately 26 miles in length, of which the lower two-thirds follow a natural meandering course through the Black Sands region. In this area, the wasteway is 0.5 mile wide in places, creating numerous arms and shallow lakes. From the air, it appears that numerous wetlands and small lakes lying to either side were created by subsurface wasteway flow. The lakes in this study lie south of the wasteway at a distance of a few yards up to 3,400 ft. The closest, Desert Lake, was formed by diking an arm of the wasteway.

If surface waters are maintained by wasteway flows, we should see a decrease in annual discharge of the wasteway corresponding to decreasing lake levels. Figure 5.15 illustrates the annual discharge of Winchester Wasteway from 1969 through 1979. Annual discharge increased to a peak of 82,078 acre-feet in 1974 and has steadily declined to 72,367 acre-feet in 1979. This decline in wasteway discharge positively correlates with declining lake levels. Figure 5.16 shows the period of greatest decline in wasteway discharge occurs from October through March, the nonirrigation months. In comparison, figure 5.17 shows discharge during the remaining months, April through September, fluctuates around 36,000 acre-feet for this 11-year period.

These results suggest a time lag exists in which ground water removed for irrigation is replenished by wasteway flows. This recharging of the water table is constant throughout the year and only appears to be greatest during the nonirrigation season. This is because at this time the wasteway does

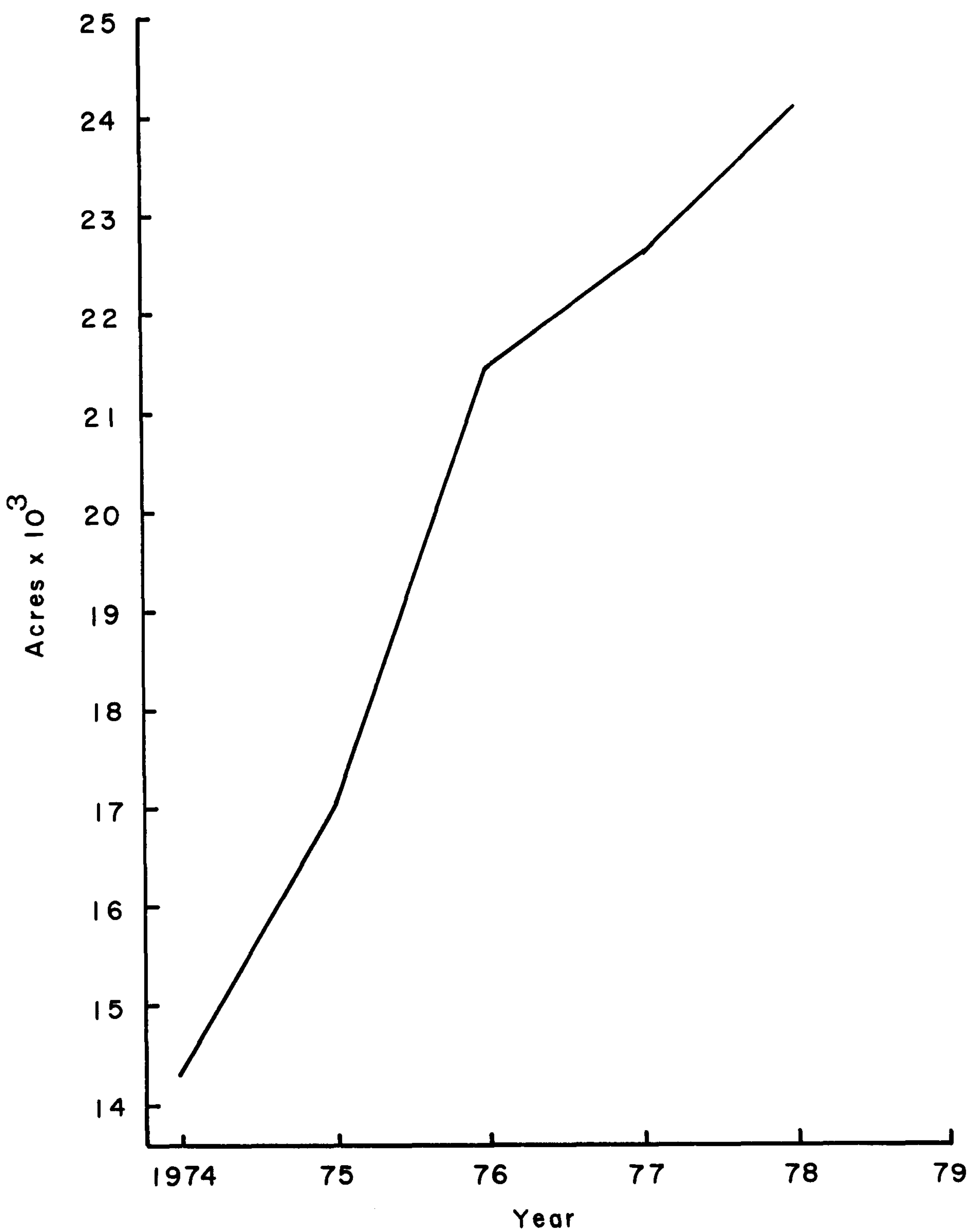


Figure 5.13.–Acreage irrigated using ground water from the upper aquifer. The data are for five townships in the Quincy subarea adjacent to the Winchester Wasteway and include T. 18 N., R. 25 and 26 E., T. 19 N., R. 25 and 26 E., and T. 20 N., R. 25 E.

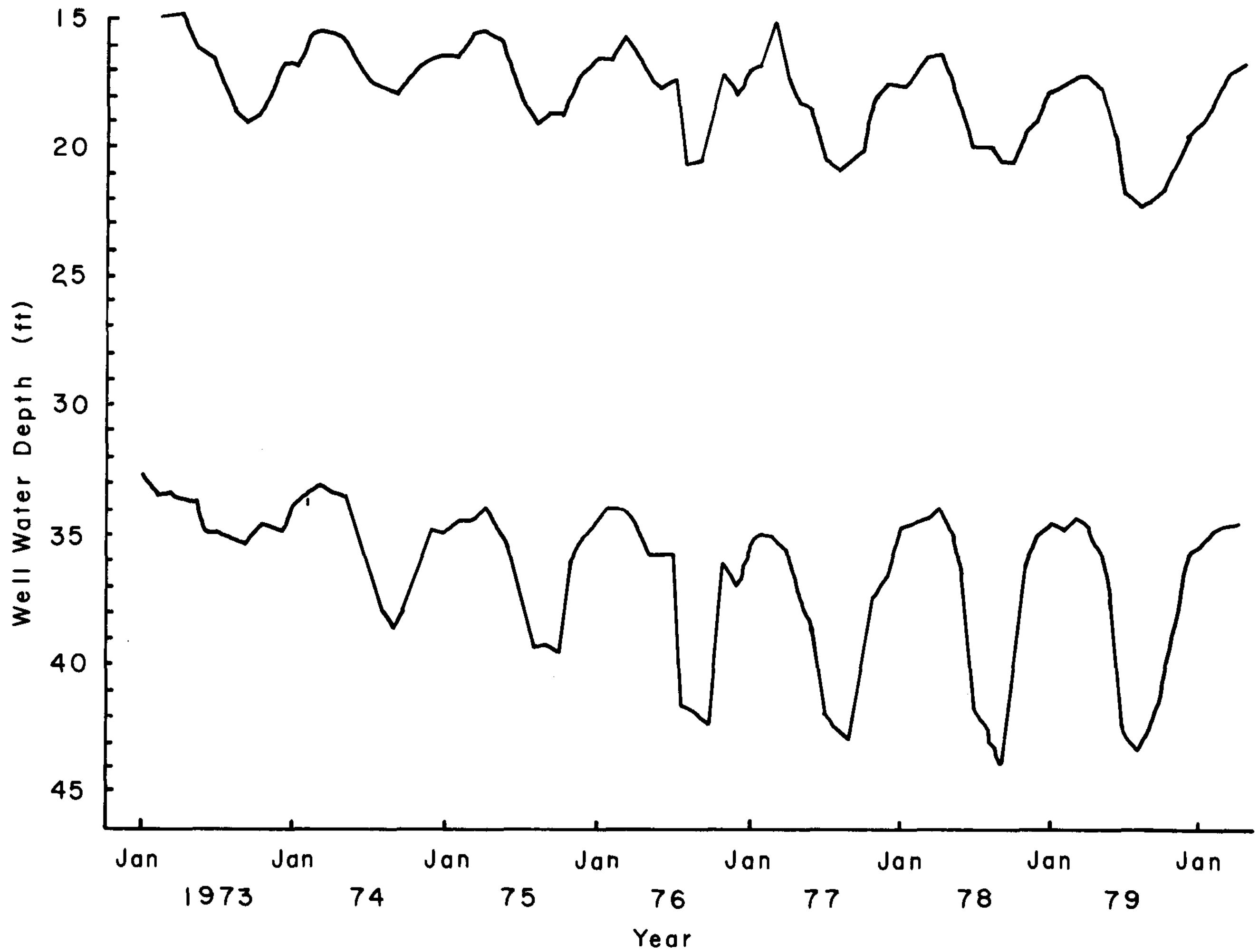


Figure 5.14.–Annual fluctuations of two wells in the Black Sands region showing decreasing water levels. Data are from USBR, Ephrata, Washington.

not receive additional irrigation return flows. As a result, the total discharge is lower. If ground-water removal continues, it will be at the expense of surface waters dependent upon wasteway flow to maintain their level.

The Black Sands region encompasses 5 of the 15 townships within the Quincy Basin subarea. Ground-water removal from this area is regulated by the Washington State Department of Ecology on a permit basis. A total of 177,000 acre-feet of ground water has been authorized to irrigate 50,570 acres. As of October 1979, a total of 271 permits have been issued for ground-water removal to irrigate 33,459 acres. More than 72 percent of this amount is pumped from the Black Sands region. Not all of the permits issued are being used because of the time required to drill a well, equipment malfunctions, and current economic constraints. This is an alarming fact considering signs of pumping stress are already appearing and less than 66 percent of the authorized amount of ground water is being utilized. Direct pumping from surface water sources is also increasing. Although small compared to ground-water use, direct pumping from Winchester Wasteway removed 578 acre-feet of water in 1978. Frenchman Hills Wasteway is a major contributor to the surface and ground water sources to the west and south reaches of the Black Sands region. Subsurface flows of both wasteways probably mingle in this area creating a common source of ground water. Direct pumping from Frenchman Hills Wasteway has increased from 574 acre-feet in 1974 to 3,777 acre-feet of water in 1978. This amount is sure to increase in the future. With 34 percent of the authorized acreage yet to be irrigated, it is possible that wetlands within this region may be reduced. This will impact waterfowl populations, as well as

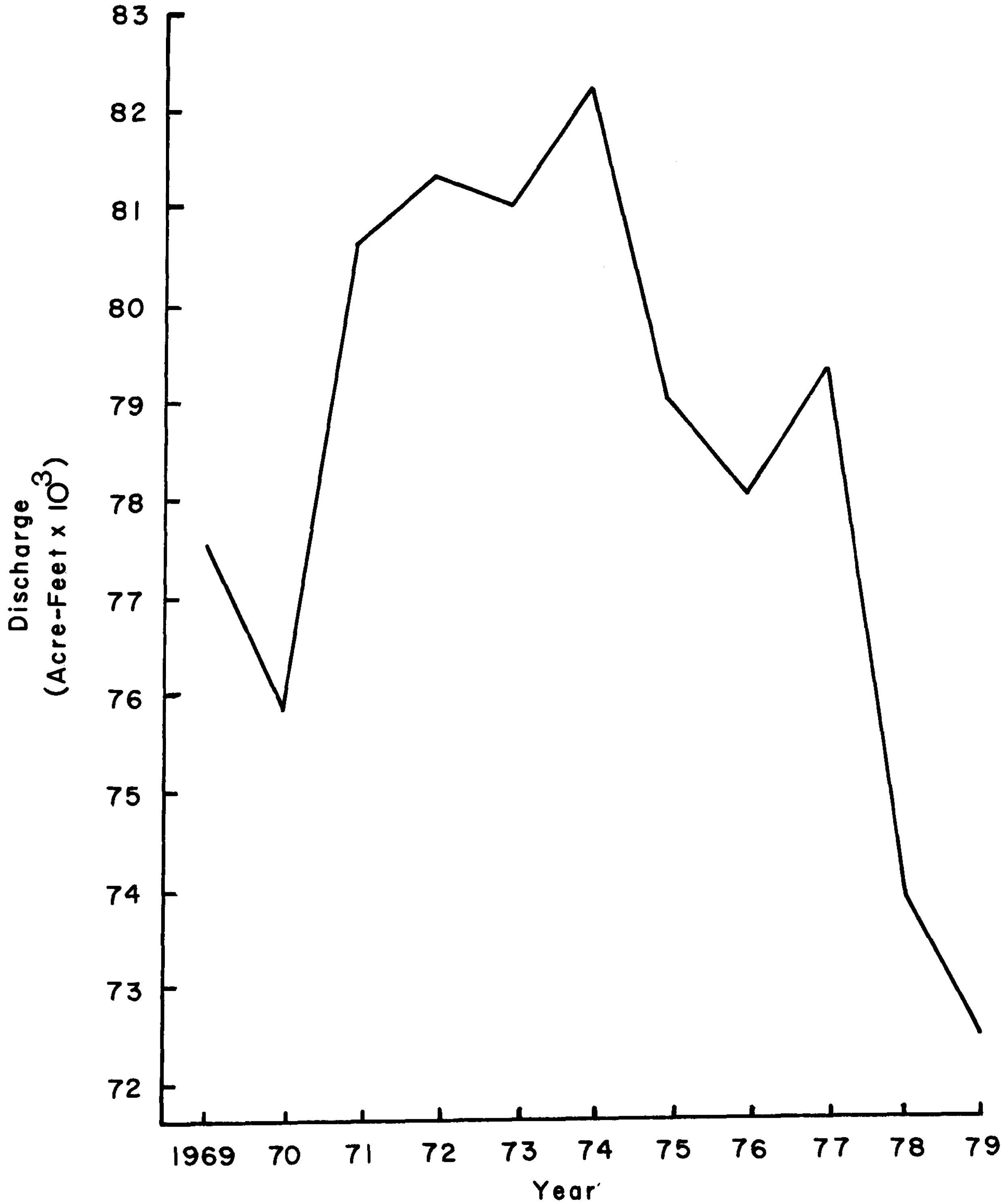


Figure 5.15.–Annual discharge of Winchester Wasteway for the years 1969 through 1979 at a point near its confluence with Potholes Reservoir, Grant County, Washington.

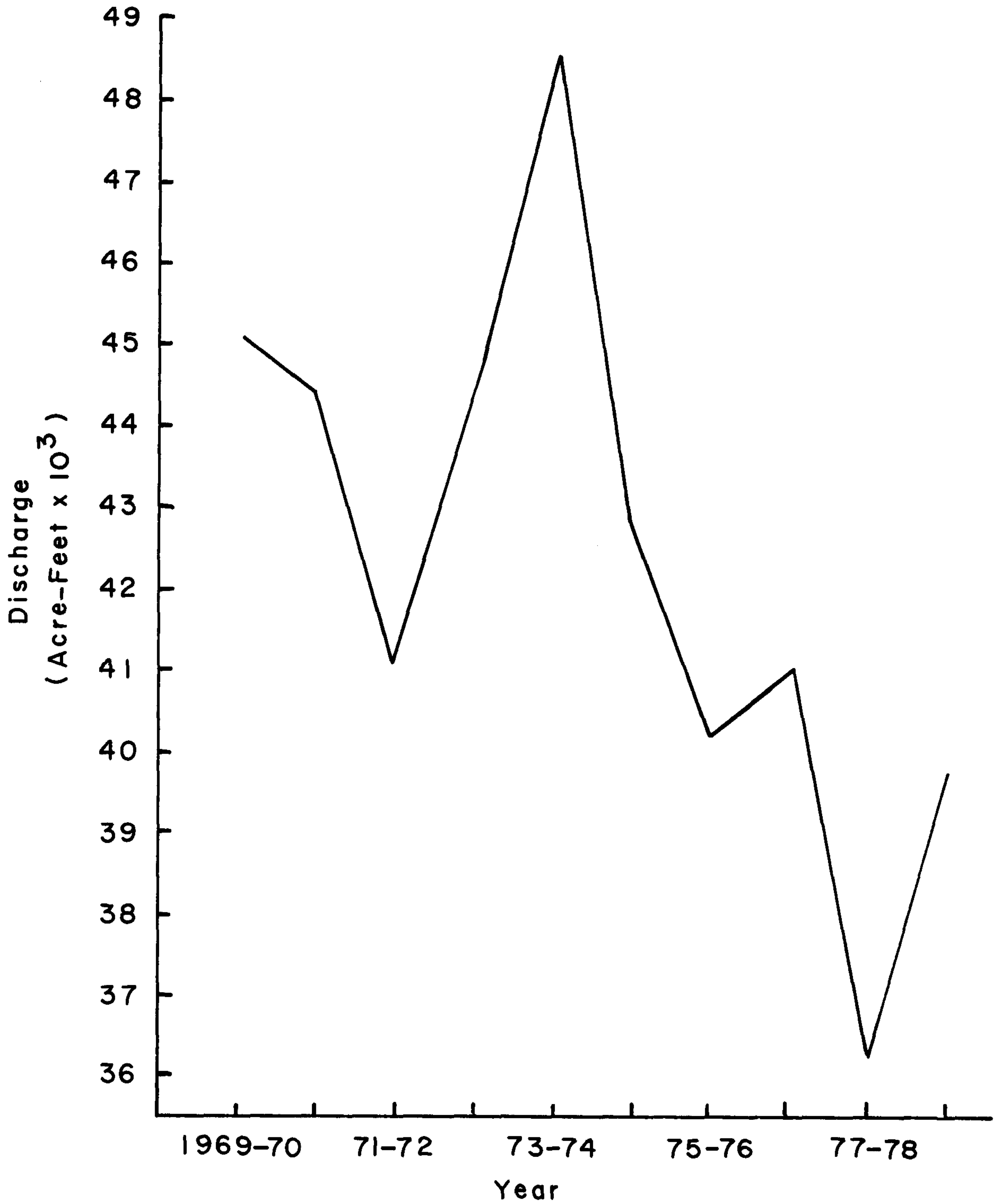


Figure 5.16.–Total discharge of Winchester Wasteway for the nonirrigable months of October through March during the years 1969 through 1979.

other wildlife species dependent upon this type of habitat. This area receives extensive use by waterfowl for resting and feeding during migration. It also provides for a significant portion of the Columbia Basin waterfowl brood production.

If lake levels continue to decline, the existing fishery will eventually be impacted. Using Harris Lake as an example, a loss in surface acreage and volume of 18 and 31 percent, respectively, can occur with a 2-foot drop in water level. The mean depth will decrease from 5.9 to 4.9 ft., and a large portion of the benthic food producing areas of the lake will be lost. During summer months, emergent aquatic vegetation will gradually diminish the open water space, speeding the process of aging and the eventual filling of the

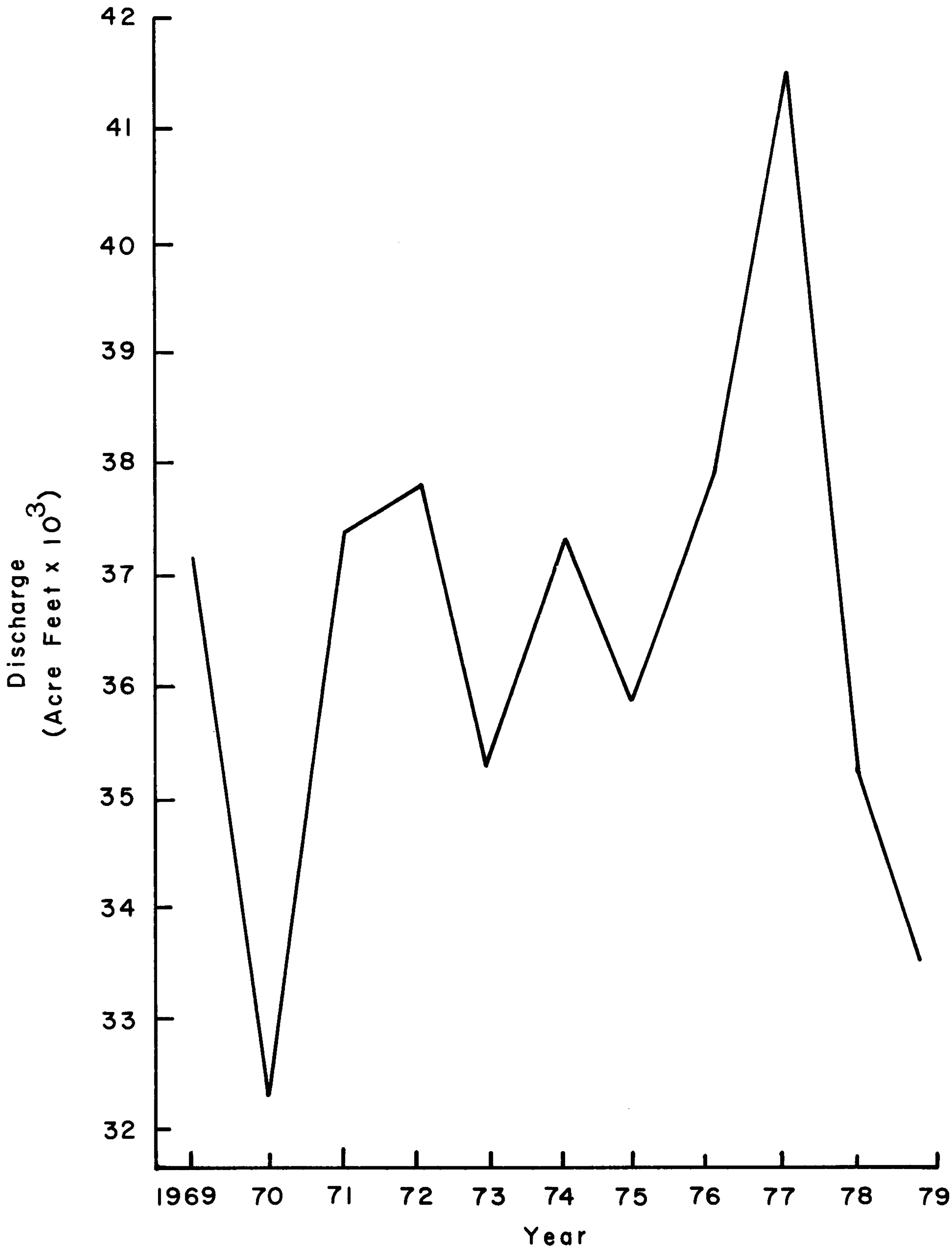


Figure 5.17.-Total discharge of Winchester Wasteway for the irrigable months of April through September during the years 1969 through 1979.

lake. In winters of prolonged ice and snow cover, anaerobic decomposition of these plants will push oxygen levels in the water towards zero, resulting in partial or complete fish kills. These same conditions will eventually prevail at all the lakes in this area if water levels continue to decline. At the current rate of decline, it will take Harris Lake an estimated 7.79 years to drop 2 ft. Using August 21, 1975, as the base year, this level will be reached approximately June 3, 1983.

Numerous shallow impoundments adjacent to Winchester Wasteway provide good largemouth bass fishing for those anglers willing to hike or canoe into the area. Without adequate depth, bass populations will be stressed as water temperatures increase and oxygen levels drop. Largemouth bass prefer temperatures of about 27 °C (80 °F) but above 30 °C (86 °F), respiration becomes difficult (Johnson and Charlton 1960) [12]. They can tolerate oxygen levels below 2.0 p/m, but die at concentrations below 1.5 p/m (Whitmore *et al.* 1960 [13]; Cooper and Washburn 1949 [14]; Moss and Scott 1961 [15]). Surface water temperatures in these shallow impoundments exceed 28 °C (82 °F) and oxygen levels drop to 2.0 p/m during the month of July. These limits may be exceeded at lower water levels. Severe winter conditions pose a threat to fish populations by completely freezing the shallow littoral area of these impoundments. This forces fish populations to compete for limited space and in some situations, oxygen as well.

AQUATIC PLANT CONTROL

Some species of aquatic plants are a nuisance to irrigators because they block the channels of water delivery structures. This results in reduced flows, head loss, and in severe cases, overflow. Earthen channels are subject to bank erosion when impeded flows are forced shoreward. All of this can be equated into higher water costs for increased operation and maintenance.

There are considerable fishery benefits attributable to aquatic plants that can offset the nuisance factors mentioned above. Aquatic plants provide absolutely essential instream cover for fish and invertebrate food organisms. Most instream and riparian cover features associated with naturally occurring lotic environments are absent in channelized water delivery structures. Aquatic plants compensate somewhat for these deficiencies and provide for the maintenance of a fishery.

The use of chemicals is the primary technique employed by agriculture and other industries to control aquatic plants. Copper sulfate and the aquatic herbicides acrolein and xylene are commonly used throughout the Columbia Basin. These chemicals are extremely toxic to aquatic organisms.

Drain 239, located in the southern reaches of the Quincy Irrigation District, is one of the best flowing water environments for fish growth in the Columbia Basin. However, the annual treatment of this drain with acrolein prevents the establishment of a fishery for any period longer than 1 year.

The Quincy Irrigation District, charged with operation and maintenance of drain 239, applies acrolein each spring to control aquatic plant growth. The dominant plant is watercress, *Rorippa Nasturtium-aquaticum*.

Acrolein, also known as 2-propenal or acryladehyde, is quickly absorbed by plants, reacting with sulfur containing protein and causing cellular degeneration. It irritates the mucous membrane of mammals and appears to react with the gill membrane of fish.

Working in cooperation with the Quincy Irrigation District, drain 239 was monitored before, during, and after treatment with acrolein. Our purpose was to record the chemical's effect on trout populations and any changes in flows, dissolved oxygen, alkalinity, and temperature of the water.

Methods and Materials

Drain 239 was monitored 1 day before, during, and 4 and 11 days after treatment. Once each monitoring day, five sampling locations spaced at 1-mile intervals were measured for channel width, average depth, and water velocity. Discharge was computed from these measurements. Dissolved oxygen, alkalinity, and temperature of the water were also measured at each location. Structural characteristics for drain 239 were supplied in part by USBR, Ephrata, Washington, and supplemented by onsite observations.

Estimates of fish abundance prior to treatment were calculated from a count of the visible number of fish in 200 feet of channel. This value was applied to 4.2 miles of channel for an estimate of the total number of fish in that distance. Data on the history of fish stocking in drain 239 were obtained from the WDG, Ephrata, Washington. Diversity and abundance of zooplankton were obtained from samples collected in September 1977 and March and June 1978. The presence of benthic invertebrates was determined from samples collected in May 1977.

Results and Discussion

Table 5.31 lists the structural characteristics of drain 239. Of the total 10.04 miles of drain, 4.2 miles is considered excellent trout habitat. This is attributable to water quality, substrate material, instream cover, and isolation of this reach of the drain to fish introduction from downstream.

Temperatures remain fairly constant at 13.3 °C (56 °F) to 15.5 °C (60 °F), and the water is very clear. Substrate material is composed mainly of fine gravel and sand with intermittent stretches of caliche or what is locally called hardpan. An abundance of watercress provides excellent instream cover in this reach.

Competition from other fish species is prevented by three drop structures blocking upstream passage. Two are located below and one above the 4.2 miles of drain under observation. Fish cannot enter the drain from above because of its isolation from other water delivery structures. Water entering the drain originates from seepage and irrigation drainage. Table 5.32 lists the physical, chemical, and biological features of drain 239 before, during, and after acrolein treatment.

Drain 239 was treated with acrolein on June 14, 1979, at a concentration of 0.166 p/m. According to the individual in charge of the application, this amounted to approximately 3.5 gallons entering the system during a 1-hour interval at one point in its upper reach. Calculations based on this information indicated a much higher concentration of acrolein entered the drain. Table 5.32 shows flow at the site of application was 17.14 cubic feet per second the day before treatment. Assuming identical conditions on the following day, 61,705 cubic feet or 461,556 gallons of water passed this point during a 1-hour interval. If acrolein were applied at the rate of 3.5 gallons per hour, the concentration would be 7.58 p/m. The strength of such an application could be detrimental to fish much further downstream than anticipated.

Using rainbow trout mortality as the only criteria, field test data indicate that the no-effect range of concentrations for a 4- to 8-hour exposure to acrolein is between 0.09 and 0.24 p/m and between 0.008 and 0.048 p/m for a 48-hour exposure (Bartley *et al.* 1975) [16]. From these results, it was predicted that, for a short-period application of 4 to 8 hours, a concentration above 0.20 p/m would be hazardous to trout. For the 48-hour treatment, any level above 0.02 p/m would be harmful.

The downstream distance that treated water must travel before detoxifying to these lower concentrations is considerable. Long-period applications (48 to 52 hours) of acrolein at 0.2 p/m required 30 to 40 miles downstream travel before concentration reduced to 0.02 p/m. For short-period applications of 1.1 p/m, the downstream distance where concentrations would fall below 0.2 p/m was not determined. Considering a concentration strength of 7.58 p/m for 1 hour, fish mortalities may have occurred many miles further downstream in Frenchman Hills Wasteway.

Trout reaction to acrolein was similar to fish subjected to rotenone, becoming lethargic and occasionally darting in a random manner. All fish appeared to labor for oxygen, displaying much gill activity. Dissolved oxygen and alkalinity did not change at any time during or after treatment. All observable fish were debilitated. Those not becoming lodged among aquatic plants drifted with the current. Occasionally fish were observed moving upstream by holding close to shore. Their progress

Table 5.31.—*Structural characteristics of drain 239, Columbia Basin, Washington*

Location: Beginning at the north boundary of farm unit 122 in block 78 northeast of George, Washington, then southerly to confluence with drain 645 east of Adams road.

Length (mi)	10.04
Discharge, average (ft^3/s)	40.0
Bottom width (ft)	21.4
Bank slopes	1.5:1
Bank height (ft)	10.0
Water depth (ft)	2.3
Culverts emptying into drain below I-90 crossing	11
Culverts located within the drain below I-90 crossing	4
Drop structures preventing fish passage upstream	3
Permanent irrigation pumps within drain	2

Table 5.32.—*Measurement of some physical, chemical, and biological features before, during, and after application of acrolein in drain 239 located in the Columbia Basin, Washington*

Feature	Date			
	6/13/79	6/14/79[a]	6/18/79	6/25/79
Total No. Fish				
Rainbow[b]	388	388	0	0
Brown[b]	388	388	0	0
Brook[c]	1,024	1,024	0	0
Other	0	0	0	0
Location 1[d]				
Total width (ft)	24.00		23.00	22.00
Average depth (ft)	3.00		3.20	2.50
Average velocity (ft/s)	0.47		0.33	0.65
Discharge (ft^3/s)	17.14		19.42	31.29
Dissolved oxygen (p/m)	9.00	8.00	8.00	9.00
pH	7.90	7.90	7.90	7.90
Temperature (°F)	55.00		54.00	
Location 2				
Total width (ft)	27.00		25.00	27.00
Average depth (ft)	3.50		3.20	3.40
Average velocity (ft/s)	0.40		0.41	0.63
Discharge (ft^3/s)	39.52		33.80	51.86
Dissolved oxygen (p/m)	11.00	11.00	10.00	9.00
pH	7.90	7.90	7.90	7.90
Temperature (°F)	56.00		55.00	
Location 3				
Total width (ft)	20.00		20.00	20.00
Average depth (ft)	2.00		2.30	2.40
Average velocity (ft/s)	1.13		1.25	1.45
Discharge (ft^3/s)	45.86	12.00	11.00	11.00
pH	8.10	7.90	7.90	7.90
Temperature (°F)	57.00		52.00	
Location 4				
Total width (ft)	18.00		19.00	20.00
Average depth (ft)	1.10		0.92	1.50
Average velocity (ft/s)	3.12		3.00	3.23
Discharge (ft^3/s)	65.37		48.94	73.41
Dissolved oxygen (p/m)	13.00	12.00	12.00	12.00
pH	8.30	8.10	7.90	7.90
Temperature (°F)	59.00			

Table 5.32.—*Measurement of some physical, chemical, and biological features before, during, and after application of acrolein in drain 239 located in the Columbia Basin, Washington*—Continued

Feature	Date			
	6/13/79	6/14/79[a]	6/18/79	6/25/79
Location 5				
Total width (ft)	18.00		18.00	19.00
Average depth (ft)	2.10		2.20	2.40
Average velocity (ft/s)	1.15		1.06	1.64
Discharge (ft^3/s)	40.23		39.49	54.79
Dissolved oxygen (p/m)	13.00	12.00	11.00	13.00
pH	8.30	8.30	7.90	7.90
Temperature (°F)	58.00			

[a] Date of acrolein treatment.
[b] Estimated number of rainbow and brown trout in 4.2 miles of drain.
[c] Estimated number of brook trout planted June 11, 1979.
[d] Site of acrolein application.

was not far, usually 20 to 50 feet, before continuing with the drift. No live fish were observed in the drain 4 days after treatment. A visual count on that day revealed 18 dead adult trout in a 4.2-mile section below the point of chemical introduction. At that time, the aquatic plants in this section appeared undisturbed. Undoubtedly, many fish died within the clusters of watercress and therefore were not visible. The remainder were either covered with sand-silt or swept downstream with the drift.

A considerable number of fish were known to be in the drain prior to treatment (table 5.32). Nine months before application, the treated section received a plant of 1,007 each, rainbow and brown trout. Winter survival was good as many fish were observed during a routine check of the drain in April 1979. Angling mortalities were not considered great as this system is relatively unknown to the general public. Seven days before treatment, 121 adult trout were counted while driving this section and 89 on the day of treatment. It is reasonable to assume more fish were present than were counted, considering the dense clusters of watercress. A lack of communication between the Irrigation District and Game Department resulted in an additional 1,024 brook trout fry planted in this section 3 days prior to treatment. Predation and downstream drift undoubtedly accounted for the removal of some of the fry plant from this section. However, large numbers of brook trout fry were observed throughout this area on the day of the treatment. No other fish species were seen. At that time, seven adult trout were counted in the first 200 feet of drain below the site of application. Assuming this is a representative figure, 776 adult fish were estimated to be in 4.2 miles of drain. Counting the recent fry plant, this amounts to about 1,800 trout for this section of drain. Most of these fish probably died from exposure to acrolein. Other fish may have passed over the downstream drop structures while drifting with the current.

Aquatic invertebrates probably sustained a complete kill within the study section of drain 239. Mortalities were sure to have occurred further downstream but were not measured. Aquatic oligochaetes were observed littering the bottom of the upper drain for days after treatment. Tables 5.33 and 5.34 list the benthic and zooplankton invertebrates known to inhabit drain 239.

Except at individual locations, there were no great changes in the measured variables as shown in table 5.32. Irrigation return flows emptying into the drain at different locations account for fluctuations in the discharge.

Our measurements terminated 11 days after treatment because of other study commitments. At this time, plant reaction to acrolein was not great. Some clusters had dislodged from the substrate; others were turning a brown color. Removal of all aquatic plants would lower water levels and increase velocities. At that time, average depth had not changed significantly, but velocities had noticeably increased. Dissolved oxygen, alkalinity, and temperature remained unchanged at each location.

I have questioned various irrigation district employees as to the necessity of aquatic plant removal in this section of drain. The primary reason given is that aquatic plants retard flow, forcing water shoreward, and this results in bank erosion. The irrigation district is concerned that the right-of-way

Table 5.33.—*Benthic invertebrates collected May 1977 from drain 239, Columbia Basin, Washington (rank is based on the total number of organisms with one as the most abundant)*

Organism	Rank
Phylum Gastropoda	
Order Pulmonata	
Family Lymnaeidae	
Lymnaea	6
Order Aspidobranchia	
Family Neritidae	
Physa	4
Gyraulus	5
Phylum Annelida	
Class Oligochaeta	6
Phylum Crustacea	
Order Amphipoda	
Family Gammaridae	3
Phylum Insecta	
Order Ephemeroptera	
Family Bactidae	
Callibaetis	9
Order Trichoptera	
Family Hydropsychidae	5
Order Coleoptera	
Family Haliplidae	7
Family Elmidae	1
Order Diptera	
Family Tendipedidae	2

road bordering the drain will eventually be lost to erosion. There is no question that flow is impeded by aquatic plants and that erosion of both banks is severe along most reaches of this drain. As to the question of cause and effect, our observations indicate other factors may be contributing more to bank erosion than the presence of aquatic plants. The bank slopes of this drain are too steep for the sandy substrate of this area. Soil-binding vegetation cannot root deep enough to completely prevent erosion. Control programs compound the situation by applying herbicides to all of one bank and easily acessible parts of the other. In places, overhead sprinklers saturate the bank with water causing the soil to slump from above.

Possible remedies for preventing erosion would be to discontinue use of herbicides, plant various species of soil-binding vegetation along both banks, and restrict excessive irrigation along the top of the banks. Rock gabions can be used to strengthen badly eroded banks and prevent undercutting. This approach to preventing bank erosion make aquatic plant removal unnecessary, thereby assuring the continuation of a year-round trout fishery and reducing operation and maintenance costs of this section of drain 239. As an alternative, acrolein application could be restricted to every other year. This would allow for the establishment of a productive trout fishery for 1 year out of the two.

Design of future irrigation ditches should take into consideration the soil type and bank slope. A wider easement along drains will allow for stair-stepping of the banks. This reduces the bank slope and provides more area for vegetation to establish. The additional construction costs are offset by the recreational value of the fishery. Considering the production of high-quality fish protein, drain 239 is capable of growing 250 to 300 pounds of trout per acre each year if managed properly.

SUMMARY

There were no significant differences between values for lake morphometry and irrigation effect.

Groups I and II were significantly different in all water chemistry variables except SiO_2 and PO_4.

Groups I and III were significantly different in all water chemistry variables except Ca hardness, SiO_2, Ca, and NO_2.

Groups II and III were significantly different in all water chemistry variables except Ca hardness, SiO_2 and Ca.

Chemical leaching from surrounding substrate combined with slow flushing times created conditions toxic to fish.

Fish were absent from lakes with water chemistry exceeding the following: alkalinity (700 p/m), NO_3 (4.0 p/m), PO_4 (2.0 p/m), Na (400 p/m), TDS (1,400 p/m), and pH (9.1).

The buildup of chemicals to toxic levels in areas where the soil is highly alkaline is prevented in lakes directly connected to irrigation flows.

There were no significant differences in sediment chemistry between groups I and II, direct and indirect irrigation effect.

Group III, lakes without fish, differed significantly in orthophosphorus with group I and orthophosphorus and NO_3 with group II.

Table 5.34.–*Zooplankton collected in September 1977, and March and June 1978, from drain 239, Columbia Basin, Washington (rank is based on the total number of organisms per liter with one as the most abundant)*

Organism	Rank	Number per liter
Order Cladocera		
Suborder Eucladocera		
Family Daphnidae		
Daphnia galeata mendotae	1	0.460
D. pulex	15	0.011
D. schodleri	3	0.214
D. sp.	4	0.210
Scapholeberis kingi	20	0.002
Simocephalus serrulatus	20	0.002
S. vetulus	19	0.004
Family Bosminidae		
Basmina coregoni	6	0.064
B. sp.	13	0.018
Family Macrothricidae		
Llyocryptus sordidus	19	0.004
Macrothrix laticornis	20	0.002
Family Chydoridae		
Alona affinis	12	0.019
A. sp.	18	0.005
Chydorus globosus	20	0.002
Leydigia quandrangularis	20	0.002
Pleuroxus aduncus	18	0.005
Order Copepoda		
Suborder Calanoida		
Family Temoridae		
Epischura nevadensis	20	0.002
Family Diaptomidae		
Diaptomus ashlandi	5	0.100
D. oregonensis	18	0.005
D. sp.	14	0.017
D. sp.	7	0.061
Suborder Cyclopoida		
Family Cyclopidae		
Cyclops bicuspidatus thomasi	9	0.029
C. vernalis	11	0.026
Eucyclops agilis	19	0.004
E. prionophorus	16	0.007
E. speratus	8	0.041
E. sp.	15	0.011
Macrocyclops albidus	17	0.006
Mesocyclops edax	10	0.028
Cyclopidae family	2	0.223

A total of 62 species of Cladocera and Copepoda were identified from 30 lakes in the Columbia Basin.

No significant difference in the number of species of zooplankton occurs between groups I and II, direct and indirect irrigation effect, respectively. Group III, lakes void of fish, had significantly fewer zooplankton species compared to the other groups.

The abundance of benthic macroinvertebrates decreased significantly as irrigation influence increased.

No significant difference was found between perch or trout growth and mean values for lake morphometry.

No significant difference was found between perch or trout growth and mean values for sediment chemistry.

Medium and poor producing perch lakes were significantly different in 7 of the 18 water chemistry variables measured. These variables were specific conductance, pH, alkalinity, Mg, HCO_3, Cl, and anions. Good and medium producing perch lakes were significantly different in only one water chemistry variable; alkalinity. Water chemistry showed no significant difference between good and poor producing perch lakes.

Good and medium producing trout waters were significantly different in 12 of the 18 water chemistry variables. These variables were specific conductance, alkalinity, SiO_2, Mg, CO_3, SO_4, Cl, PO_4, cations, anions, Na and TDS. Good and poor trout producing waters were significantly different in 3 of the 18 water chemistry variables. These variables were NO_3, Mg, and cations. There was no significant difference in water chemistry between medium and poor producing trout lakes.

No correlation was found between perch or trout productivity and zooplankton diversity and abundance.

No correlation was found between perch or trout productivity and benthic invertebrate diversity and abundance.

Rank-frequency abundance of zooplankton and benthic invertebrate accounts for 90 percent of the weight gains in rainbow trout raised in seep lakes, indirectly affected by irrigation. Four other variables accounted for 9.59 percent of the variability in trout weight gains. These variables were lake sediment, NH_3 benthic invertebrate abundance, lake surface area, and NO_3 of the sediment. These variables can be expressed mathematically as follows: weight gains (g/day) = 0.6855 + 0.0013 (surface acres) + 0.0034 (substrate ammonia) + 0.8791 (RFI-benthic invertebrates) − 0.1747 (substrate nitrates) − 0.0142 (benthic abundance) − 0.6389 (RFI-zooplankton).

Group I, direct irrigation effect, accounted for 72 percent of the total stream miles surveyed. Groups II and III, indirect and no irrigation effect, accounted for 10 and 18 percent of the total stream miles studied, respectively.

Soil type and amount of agricultural activity seem to affect water chemistry.

Higher chemical concentrations in water are found in earthen channels versus concrete-lined channels. This is because of the leaching effect from soils of certain chemicals and irrigation return flows carrying chemically enriched water.

Only two chemical variables differ significantly between groups I and II flowing waters; alkalinity and HCO_3. There are no significant differences in water chemistry between groups I and II. Seven chemical variables differ significantly between groups II and III; specific conductance, alkalinity, Mg, HCO_3, cations, anions, and TDS.

Thirteen orders of benthic invertebrates were identified from flowing waters of the Columbia Basin, Washington.

Group I, direct irrigation effect, had the least number of benthic invertebrates per sample of substrate. Group III, no irrigation effect, had the greatest number.

Benthic invertebrate diversity increased as irrigation influence decreased.

Diptera were the most common benthic invertebrates sampled regardless of irrigation effect. In general, this is followed by Trichoptera, Coleoptera, Empheromeroptera, and Amphipoda.

Factors affecting the abundance and diversity of benthic invertebrates in flowing waters are changes in water level, velocity and chemistry associated with irrigation activities, siltation, chemical herbicides and the presence of carp.

Five water types were sampled for fish and habitat features: plunge pool, pool, riffle, glide, and flat.

Glides accounted for 61 percent of the total area sampled. Pools, riffles, and flats accounted for 13.3, 9.5, and 11.8 percent of the total area sampled, respectively. Plunge pools accounted for 4.4 percent of the total.

Group I, direct irrigation effect, accounted for most of the glides and plunge pools sampled. This is a result of their structured channels.

Fifteen species of fish were collected in electroshocking operations. Except for brook trout, largemouth and smallmouth bass, the same species generally occurred in each group of waters.

Group III, no irrigation effect, produced 56 percent of the total number of fish collected. This group also had the least acreage sampled at 6.11 acre-feet. Groups I and II, direct and indirect irrigation effect, provided 32 and 11 percent, respectively, of the total number of fish collected while accounting for 87 percent of all flowing water sampled.

Trout abundance was greatest in group III waters, no irrigation influence. Groups I and II were about equal.

The greatest diversity of spiny-ray game fish occurred in group I waters.

Plunge pools were utilized by trout more than any other water type. Trout utilized flats least of all.

The greatest biomass of fish, regardless of species, was found in plunge pools, followed in decreasing order by pools, riffles, glides, and flats.

Using stepwise linear regression analysis, nine linear models were developed to estimate trout biomass in flowing waters. Three models are for rainbow trout, three models for brown trout, and three models for all trout for groups I, II, and III flowing waters. One model each was developed for spiny-ray game fish and nongame fish in group I waters, direct irrigation effect.

A downward trend exists in the level of lakes in the Desert Habitat Management Area.

Annual precipitation and evaporation are not a factor in the decreasing levels of these lakes.

Ground-water levels in the vicinity of the seven lakes studied have increased over the past 20 years.

Ground-water levels 10 to 15 miles north of the seven lakes studied have leveled off or started to decrease in recent years. This is the initial sign of pumping stress in this area.

Wasteway flows are the primary water source of the seven lakes studied.

The annual discharge of water through Winchester Wasteway reached a peak in 1974. Since that time, it has continually decreased.

Wasteway flows continually replenish ground-water sources which are being lowered by excessive pumping. As a result, the annual discharge of wasteway flows is declining.

Continued decline of ground-water sources will result in further decline of surface waters of the Black Sands region. Fish and wildlife will be adversely impacted. Ground-water and surface-water pumping should be maintained at the 1974 level.

Restoring wasteway flows to 1974 levels could be accomplished by a reduction in pumping or through increased wasteway flow and no new pumping.

Bank erosion along drain 239 is considered by Quincy Irrigation District to be caused by aquatic plants impeding flows and forcing water shoreward.

The yearly application of acrolein to control aquatic plant growth results in complete mortality of fish and invertebrates in drain 239.

Concentrations of acrolein above 0.24 p/m are harmful to fish and invertebrates. Concentrations necessary to control aquatic plant growth are lethal to fish and invertebrates.

Dissolved oxygen, alkalinity, and water temperature remained unchanged after an acrolein application.

Other factors contributing more to bank erosion along drain 239 include: (1) bank slopes too steep for sandy substrate; (2) inadequate soil-binding vegetation along the banks; (3) periodic spraying of herbicides remove soil-binding vegetation from banks; and (4) overhead sprinklers saturate bank shoulders, causing slumping.

Further erosion can be reduced considerably by: (1) discontinuing use of herbicides on banks; (2) planting various soil-binding vegetation along both banks; (3) restricting irrigation along shoulder of banks; and (4) placing rock gabions in areas of severe erosion.

To maintain the trout fishery: (1) discontinue use of aquatic herbicides, or apply every second or third year; (2) reduce erosion as recommended above.

Drain 239 has excellent trout habitat in its upper 4.2-mile reach. If managed properly, it can produce an estimated 250 to 300 pounds of trout per acre each year.

CONCLUSIONS

Based on growth rate analysis and WDG planting records, static waters of the Columbia Basin are being managed at about their optimum level for trout production. Seep lakes, isolated from irrigation flows, produce the greatest poundage of fish per acre when managed as a single-species fishery. Rainbow trout are the species of choice as they are easiest to raise, fast growing, and use most levels of the food chain.

Warm water fish biologists for the Game Department are experimenting with stocking largemouth bass and bluegills in selected seep lakes.[4] This program has the potential of providing quality angling for spiny-ray enthusiasts. The most successful waters will be those also capable of good trout production. Since bass and bluegill fry use the same food items as trout, stocking them in poor or marginal trout waters will result in no better production. A review of the management of Stan Coffin Lake will verify this claim.

Yellow perch do very well in certain seep lakes. Before it was rehabilitated in 1975, March Lake produced perch of a size and quality comparable to Coffee Pot Lake. Anglers reported using both wet and dry flies as well as assorted spinners to catch perch from this 15- to 20-acre lake.[5]

Waters directly connected to irrigation flows are best managed as a mixed species fishery for numerous reasons. Because of continual fish recruitment from other sources, these waters are impossible to manage for a single fish species. Also, because of inflow and outflow, flushing time in these waters is shorter compared to seep lakes. This results in more dilute water chemistry, higher turbidity, and changes in the amount of euphotic zone available for primary production. All of these factors affect the limnology of reservoirs, resulting in differing rates of productivity.

Irrigation reservoirs, such as Banks Lake, Potholes Reservoir, and Scootney Reservoir, receive the most water-dependent recreation of any waters studied. This is not to say trout-only waters are not significant in contributing to Columbia Basin angling; they are. However, irrigation reservoirs are multiuse waters, open year-round for camping, fishing, and other forms of recreation as weather and regulation allow. They receive and sustain much greater levels of angler pressure because of their physical size, multiaccess points, and mixed species fishery. Angling is probably the prime factor in attracting recreationists to these waters. Factors contributing to the success of the reservoir fisheries are varied, but one of primary importance is the connection to irrigation canals. Fish entrainment in the Main Canal exiting Banks Lake had a tremendous impact on that lake's kokanee and rainbow fishery (Stober, *et al.* 1977) [17]. Placement of a barrier net at the head of Main Canal significantly reduced the downstream passage of adult salmonids and other fish species. Local anglers, however, complained of a resulting decline in the fishery of Billy Clapp Lake, a recipient of Main Canal discharge below Banks Lake.

Numerous examples of the importance of inflow-outflow channels to reservoir fisheries exist in the Columbia Basin. Trophy-size rainbow trout and large walleye migrate upstream from Soda Lake to feed on juvenile perch, bass, crappie, and bluegill as they exit Potholes Reservoir through Potholes East Canal. Large boulders and white water create ideal cover for these big fish while they feed on juveniles stunned and disorientated by the force of water exiting Potholes Reservoir. Many other game fish species congregate in this relatively small area of white and turbulent water. Accessibility to food and protective cover are the basic reasons for the success of this fishery.

Potholes East Canal passes through Soda, Long, and Campbell Lakes on its journey to Scootney Reservoir. The fisheries in these lakes are dependent upon nutrients and food items brought in by the canal. As long as water remains in the canal, adult fish can travel between lakes maximizing use of food, cover, and space while providing angling enjoyment that would not exist otherwise. While some reservoirs may benefit from screening to prevent fish migration, others depend on the exchange of juvenile and adult fish to maintain a fishery.

The sport fishery in both Potholes and Scootney Reservoirs could possibly be enhanced by the introduction of striped bass (*Morone saxatilis*). From all indications of the physical, chemical, and biological environment of these two reservoirs, striped bass would do well. Arguments that stripers, as predators, would impact existing game fish populations are not supported in the literature. Adult stripers are opportunistic and will feed on what is available. The preponderence of juvenile carp, sucker, squawfish, and other nongame fish in these reservoirs would provide an adequate food source for stripers 2+ years of age. Benthic and zooplankton populations in these reservoirs are adequate to support juvenile stripers in their first 2 years of growth.

Striped bass have established populations in five major rivers of Oregon and have been successfully transplanted into reservoirs throughout the United States. One of the more successful plants has been in the river-reservoir system of the lower Colorado River, first stocked in 1959 with 890 stripers averaging 69 mm (3.5 inches) in length, (St. Amant

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[4] W. Zook, personal communication.
[5] R. Steel, personal communication.

1959) [18]. Striped bass fry can be obtained from either Oregon or California Fish and Game Departments.

Many attempts have been made by fishery biologists to identify and quantify aquatic habitat as it relates to fish biomass. The results of this study have added a little more to the growing body of information on this subject. In this study, water type appears to have the greatest influence on fish biomass of any variable examined. Deep, slow pools with extensive cover had the most stable trout populations of any water type in Little Prickly Pear Creek, Montana (Lewis 1969) [19]. In that study, cover was rated as the percent of stream banks, brush, undercut banks, overhanging vegetation, and miscellaneous riparian plants. The important plant species constituting cover were willow (*Salix* sp.) and dogwood (Cornus sp.). Lewis (1969) [19] also found that current velocity accounted for significant variations in trout numbers, especially rainbow trout. Depth, velocity, substrate, and temperature were found to be the most important variables accounting for the presence of salmonids in streams of the western United States (Bovee 1978) [20].

The list continues with each researcher discovering many of the same and some new variables accounting for variations in fish biomass in streams. Given the basic parameters in which to survive (temperature, pH, oxygen, water chemistry, and food), and a few of the variables identified above, trout and other game fish species will thrive.

Recommendations for existing streams, whether they be natural or artifically constructed, are to retain as much cover as possible. This includes all types of riparian vegetation and near-stream shrubs and trees. If in doubt, plant more trees, shrubs, and grasses. Especially important are submerged aquatic plants, as they provide instream cover for both fish and invertebrates. Morphometric features that will enhance fish production include deep pools spaced throughout the channel and accompanied by boulders placed instream. In shallow areas, placement of rubble, rocks 3 to 6 inches in diameter, will create nursery areas for juvenile fish while providing attachment for many benthic invertebrate species.

These recommendations pertain also to newly constructed drains and wasteways. Where possible, and as frequently as economics allow, drop structures should be installed. The plunge pools created by these structures are utilized extensively by game fish. Drop structures also aid in oxygenation of the water and prevent upstream migration of undesirable fish species.

Finally, water velocities should be maintained above 0.5 ft/s. In sites where velocities dropped below 0.5 ft/s, trout and other game fish were absent.

Declining surface and ground-water levels create problems for numerous agencies and resource users, not the least being irrigators. In seeking a solution to this problem, primary consideration should be given to multiple use of the water. Wildlife populations and their associated habitat have developed a dependency upon the surface water of this area as it has become available. Allowing wetlands, marshes, seep lakes, and wasteway flows to recede will reduce the habitat base and cause an eventual decline in wildlife populations.

Alternatives to a continuing decline in water levels are to maintain surface waters at their present level or restore them the their high of 1974. To maintain existing levels, no new permits should be issued for ground water removal in the five townships encompassing the Black Sands region. This should include permits for surface water withdrawals from drains and wasteways passing through this area. Groundwater permits and surface water contracts are not permanent water rights. As such, they are regulated by the issuing agency in the best interest of the resource.

Restoring surface water to 1974 levels could be accomplished by a reduction in pumping or through increased wasteway flow and no new pumping. The latter seems more acceptable in view of a general reluctance to undo that which is already done. Additional flows can be routed through Winchester Wasteway via West Canal. This could be accomplished whenever water is available, but should total 9,700 acre-feet annually to achieve the 1974 discharge. Ideally, an increase in wasteway flow of between 15 and 20 ft^3/s throughout the year is most desirable. However, problems associated with operation and maintenance of West Canal and additional water costs hinder the feasibility of this approach. An alternative source of water is drain 645 which is continually supplied from four pumped wells used to prevent farmed lands from becoming wet. The wells are located approximately 5 miles west of the head of Winchester Wasteway. A ditch or pipe diversion from the pumps to the wasteway can provide the necessary link. The initial cost of construction and materials for the delivery structure would be the major expense. Operation and maintenance costs of the pumps are already absorbed by USBR.

This approach may be limited in that we are supplying one wetland at the expense of another. Drain 645 and its tributary drains feed directly into Frenchman Hills Wasteway. These sources contribute to surface waters along their route to Potholes Reservoir and account for a large acreage of wetlands. Removing water from drain 645 may contribute to the decline of these wetlands and seep lakes.

The alternatives suggested are only temporary solutions based upon a limited amount of data. Long-term management of the hydraulics of this area requires a more detailed study to fully assess the impact of ground-water pumping upon surface waters.

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APPENDIX A

NOMENCLATURE

NOMENCLATURE

Table A.1.—*List of common and scientific names of wildlife and plants used in the text*

Common name	Scientific name
Mammals	
Pygmy rabbit	*Sylvilagus idahoensis*
Cottontail rabbit	*S. floridanus*
White-tailed jackrabbit	*Lepus townsendii*
Marmot	*Marmota flaviventris*
Beaver	*Castor canadensis*
Small rodents	*Peromyscus maniculatus*
Small rodents	*Microtus spp.*
Muskrat	*Ondatra zibethicus*
Porcupine	*Erethyzon dorsatum*
Coyote	*Canis latrans*
Raccoon	*Procyon lotor*
Weasel	*Mustela frenata*
Badger	*Taxidea taxus*
Skunk	*Mephitis mephitis*
Elk	*Cervus elaphus*
Deer	*Odocoileus hemionus*
Birds	
Whistling swan	*Cygnus columbianus*
Western Canada goose	*Branta canadensis moffitti*
Taverner's Canada goose	*B. c. taverneri*
Mallard	*Anas platyrhynchos*
Gadwall	*A. strepera*
Wigeon	*A. americana*
Pintail	*A. acuta*
Green-winged teal	*A. carolinensis*
Blue-winged teal	*A. discors*
Cinnamon teal	*A. cyanoptera*
Shoveler	*A. clypeata*
Redhead	*Aythya americana*
Ring-necked duck	*A. collaris*
Canvasback	*A. valisineria*
Lesser scaup	*A. affinis*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*B. islandica*
Bufflehead	*B. albeola*
Ruddy duck	*Oxyura jamaicensis*
Hooded merganser	*Mergus cucullatus*
Sage grouse	*Centrocercus urophasianus*
California quail	*Lophortyx californica*
Ring-necked pheasant	*Phasianus colchicus*
Killdeer	*Charadrius vociferus*
Ring-billed gull	*Larus delawarensis*
Magpie	*Pica pica*
Raven	*Corvus corax*
Starling	*Sturnella neglecta*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Red-winged blackbird	*Agelaius phoeniceus*

Table A.1.—*List of common and scientific names of wildlife and plants used in the text*—Continued

Common name	Scientific name
Fish	
Rainbow trout	*Salmo gairdneri*
Carp	*Cyprinus carpio*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Plants	
Annual bluegrass	*Poa annua*
Sandberg bluegrass	*P. sandbergii*
Bulbous bluegrass	*P. bulbosa*
Crested wheatgrass	*Agropyron cristatum*
Blue-bunch wheatgrass	*A. spicatum*
Foxtail	*Setaria spp.*
Redtop	*Agrostis alba*
Cheatgrass	*Bromus tectorum*
Needle-and-thread	*Stipa comata*
Squirrel-tail barley	*Hordeum jubatum*
Indian ricegrass	*Oryzopsis hymenoides*
Saltgrass	*Distichlis stricta*
Great basin wildrye	*Elymus cinereus*
Scouring rush	*Equisetum hymale*
Lambsquarters	*Chenopodium album*
Kochia	*Kochia scoparia*
Russian thistle	*Salsola kali*
Knapweed	*Centaurea spp.*
Tumble mustard	*Sysimbrium altissimum*
Tansymustard	*Descurainia pinnata*
Dock	*Rumex spp.*
Pigweed	*Amaranthus spp.*
Hemp dogbane	*Aponcynum cannabinum*
Prickly lettuce	*Lactuca serriola*
Vetch	*Vicia spp.*
Scurf pea	*Psoralea lanceolata*
Big sagebrush	*Artemesia tridentata*
Rabbitbrush	*Chrysothamnus spp.*
Bitterbrush	*Purshia tridentata*
Saltbrush, greasewood	*Sarcobatus vermiculatus*
Spiny hopsage	*Grayia spinosa*
Wild rose	*Rosa woodsii*
Willow	*Salix spp.*
Muskgrass	*Chara spp.*
Coontail	*Ceratophyllum demersum*
Water milfoil	*Myriophyllum spicatum*
Sago pondweed	*Potomogeton pectinatus*
Watercress	*Rorippa naturtium-aquaticum*
Duckweed	*Lemna minor*
Hardstem bulrush	*Scirpus acutus*
Three-square bulrush	*S. americanus*
Baltic rush	*Jancus balticus*
Sedges	*Carex spp.*
Cattail	*Typha latifolia*

APPENDIX B

LAND CLASSIFICATION AND STUDY SITE LOCATION

LAND CLASSIFICATION AND STUDY SITE LOCATION

Land-Use Classification: Definitions and Comments

Classification of land use or "habitats" is included in table B.1 for the terrestrial portion of the study. The functional significance of classifying lands on the basis of agricultural use rests on the fact that various types and intensities of farming affect the variety and abundance of wildlife. Knowing this, we can compare the capacity of one land-use type to produce wildlife with that of any other type or types.

After discussing these habitat categories with various persons, there was evidence of confusion as to the definition attached to each category. The following represents our concept of category definitions.

Naturally occurring habitats (dryland habitats): "Dryland habitats" is used since it is more concise and more aptly fits the category. Wheatland is not conceived to be a naturally occurring habitat. Dryland habitats have been previously defined as those areas potentially irrigable but, as yet, either unirrigated or having only small, localized irrigated farms.

- A_1 Unfarmed and natural lands: any untilled sections. This is essentially rangeland for domestic stock, since completely undisturbed lands are scarce. It would be illogical to group rangelands with dryland grain farms because of the radical differences in vegetation between the two.
- A_2 Dryland farms: lands devoted to unirrigated agricultural crops.
- A_3 Incidentally irrigated lands: lands containing small, private irrigation developments within a larger landscape of dryland farms and rangeland.

Artifically created terrestrial habitats (irrigated habitats): areas where irrigation has been fully developed or nearly so.

- B_1 Lands with ordinary farm-oriented development (exclusively farming): this habitat category is characterized by lands devoted solely to the production of agricultural crops with no provisions in land management for wildlife maintenance or enhancement. Typically, these lands are fully utilized, exhibiting clean and intensive farming practices.
- B_2 Lands with multipurpose goals (multipurpose uses): a portion of the land is allocated for wildlife use and/or farming practices and procedures are employed that benefit wildlife along with agricultural crop production.
- B_3 Lands exclusively managed for wildlife production (exclusively wildlife): lands managed for the single purpose of producing wildlife or benefiting wildlife in some way. Irrigated farming may occur, but only to serve the goal of wildlife maintenance or enhancement.

Table B.1.—*Study site locations and land-use classifications*

Site	Location			County	Irrigation	Irrigation	Land-use category[a]					
							Dryland habitats			Irrigated habitats		
No.	sec.	tnship.	rng.		district	block	A_1	A_2	A_3	B_1	B_2	B_3
1	30	21	26	Grant	Quincy	73					X	
2	2	20	24	Grant	Quincy	73				X		
3	2	20	23	Grant	Quincy	73				X		
4	14	20	23	Grant	Quincy	73, 74					X	
5	16	20	24	Grant	Quincy	72				X		
6	17	20	25	Grant	Quincy	72					X	
7	22	20	24	Grant	Quincy	72				X		
8	28	20	23	Grant	Quincy	74				X		
9	32	20	24	Grant	Quincy	72				X		
10	21	19	25	Grant	Quincy	None					X	
11	24	19	25	Grant	Quincy	89					X	
12	26	19	25	Grant	Quincy	None					X	
13	36	19	25	Grant	Quincy	None					X	
14	17	18	24	Grant	Quincy	78				X		
15	29	18	24	Grant	Quincy	78, 79				X		
16	29	17	24	Grant	Quincy	82					X	
17	34	17	24	Grant	Quincy	82					X	
18	19	17	27	Grant	Quincy	80					X	
19	18	17	28	Grant	Quincy	80					X	
20	31	17	27	Grant	Quincy	87					X	
21	6	16	27	Grant	Quincy	73					X	
22	35	17	27	Grant	Quincy	80, 87					X	
23	11	19	23	Grant	Quincy	None						X
24	24	19	23	Grant	Quincy	None						X
25	SE¼26 SW¼25 NE¼35 NW¼36	18	24	Grant	Quincy	78						X
26	23	20	28	Grant	Quincy	None						X
27	11	17	25	Grant	Quincy	None						X
28	8	17	26	Grant	Quincy	None						X
29	9	17	27	Grant	Quincy	None						X
30	16	18	26	Grant	Quincy	None						X
31	15	18	26	Grant	Quincy	None						X
32	9	18	26	Grant	Quincy	None						X
33	E½15 W½14	20	28	Grant	East	None						X
35	1	20	28	Grant	East	40					X	
36	9	20	28	Grant	East	40					X	
37	19	20	29	Grant	East	40				X		
38	32	20	29	Grant	East	40, 41				X		
39	7	19	29	Grant	East	41				X		
40	16	19	29	Grant	East	41				X		
41	20	19	29	Grant	East	41				X		
42	19	18	30	Grant	East	44					X	
43	23	18	30	Grant	East	43					X	
44	35	18	30	Grant	East	43, 44					X	
45	1	17	29	Grant	East	44				X		
46	18	17	31	Adams	East	43, 44					X	
47	26	17	29	Grant	East	44					X	
48	22	16	29	Adams	East	45					X	
49	23	16	29	Adams	East	45				X		

Table B.1.—*Study site locations and land-use classifications*—Continued

Site No.	Location sec.	tnship.	rng.	County	Irrigation district	Irrigation block	Land-use category[a] Dryland habitats A_1	A_2	A_3	Irrigated habitats B_1	B_2	B_3
50	15	15	29	Adams	East	45				X		
51	26	15	29	Adams	East	45					X	
52	20	15	30	Adams	East	47					X	
53	27	15	30	Adams	East	47				X		
54	9	14	30	Franklin	South	11					X	
55	21	14	30	Franklin	South	11				X		
56	1	13	28	Franklin	South	23					X	
58	29	13	30	Franklin	South	12, 14, 18					X	
59	34	13	29	Franklin	South	19				X		
60	11	12	29	Franklin	South	19, 14					X	
61	16	12	29	Franklin	South	19				X		
62	36	12	29	Franklin	South	16					X	
63	4	11	29	Franklin	South	15				X		
64	12	11	29	Franklin	South	15, 16				X		
65	7	11	30	Franklin	South	16					X	
66	20	11	29	Franklin	South	15				X		
67	34	11	29	Franklin	South	15				X		
68	31	11	30	Franklin	South	16					X	
69	9	10	30	Franklin	South	17					X	
70	15	10	30	Franklin	South	17					X	
71	20	10	30	Franklin	South	17					X	
72	16	10	29	Franklin	South	16					X	
73	28	15	25	Grant	South	25					X	
74	35	15	25	Grant	South	25					X	
75	S½14											
	N½23	17	28	Grant	Quincy	None						X
76	17	16	28	Adams	Quincy	None						X
77	S¼13											
	N¼24	16	27	Grant	Quincy	None						X
78	29	16	28	Adams	Quincy	None						X
79	28	16	27	Grant	Quincy	None						X
80	33	16	27	Grant	Quincy	None						X
87	16	25	31	Lincoln	None	None			X			
88	27	26	32	Lincoln	None	None	X					
89	20	25	32	Lincoln	None	None		X				
90	18	24	32	Lincoln	None	None		X				
91	28	23	32	Lincoln	None	None	X					
93	5	21	32	Lincoln	None	None	X					
94	15	23	29	Grant	None	None		X				
95	9	22	30	Grant	None	None		X				
96	20	22	29	Grant	None	None	X					
97	21	21	30	Grant	None	None	X					
98	9	19	30	Grant	None	None		X				
99	30	19	30	Grant	None	None			X			
100	7	21	32	Lincoln	None	None	X					
101	E½35											
	W½36	19	31	Adams	None	None		X				
102	6	17	32	Adams	None	None			X			
103	26	17	30	Grant	None	None		X				
104	35	17	31	Adams	None	None			X			
105	27	16	32	Adams	None	None			X			

Table B.1.—*Study site locations and land-use classifications*—Continued

Site No.	Location sec.	Location tnship.	Location rng.	County	Irrigation district	Irrigation block	Land-use category[a] Dryland habitats A_1	A_2	A_3	Irrigated habitats B_1	B_2	B_3
106	16	15	33	Adams	None	None		X				
107	10	15	31	Adams	None	None			X			
108	1	14	31	Franklin	None	None		X				
109	27	11	17	Yakima	Wapato	None					X	
110	9	11	18	Yakima	Wapato	None				X		
111	36	11	18	Yakima	Wapato	None				X		
112	18	11	19	Yakima	Wapato	None				X		
113	18	10	21	Yakima	Wapato	None				X		
114	18	10	22	Yakima	Sunnyside	None					X	
115	36	10	22	Yakima	Sunnyside	None					X	
116	27	10	23	Yakima	Rosa	None					X	
117	9	9	22	Yakima	Sunnyside	None				X		
118	21	9	22	Yakima	Sunnyside	None					X	
119	9	9	23	Yakima	Sunnyside	None				X		
120	9	8	22	Yakima	Wapato	None					X	
121	13	17	12	Yakima							X	
122	15	17	12	Yakima							X	
123	22	17	12	Yakima							X	
124	27	24	32	Lincoln			X					
125	14	23	31	Lincoln			X					
126	12	23	32	Lincoln			X					
127	13	23	32	Lincoln				X				
128	19	23	33	Lincoln				X				
129	14	22	32	Lincoln			X					
130	24	22	32	Lincoln				X				
131	6	22	30	Grant			X					
132	11	22	30	Grant					X			
133	9	22	29	Grant			X					
134	23	20	31	Adams				X				
135	24	15	31	Adams				X				
136	31	21	24	Grant	Quincy	73				X		
137	16	21	27	Grant	Quincy	None					X	

[a]A_1 = unfarmed lands.
A_2 = dryland farming.
A_3 = incidentally irrigated farming.
B_1 = intensive farming.
B_2 = multipurpose.
B_3 = exclusively wildlife.

Table B.2.—*Distribution of study sites within each rank by land use class, intensively farmed (B_1), multipurpose (B_2), and wildlife (B_3) for six site characteristics (numbers within columns are the number of study sites)*

Rank[a]	Surface wetlands			Topography			No. of vegetation types			No. of fields			Adjoining sections with untilled land			Untilled land on sites		
	B_1	B_2	B_3	B_1	B_2	B_3	B_1	B_2	B_3	B_1	B_2	B_3	B_1	B_2	B_3	B_1	B_2	B_3
0	0	5[b]	0	21	24	6	—	—	—	—	—	—	9	6	0	15	—	0
1	25	20	0	8	10	3	1	0	4	0	0	0	7	5	0	3	—	0
2	4	9	0	0	3	4	7	11	10	0	0	0	2	5	0	4	—	0
3	2	12	18	2	9	3	14	17	4	0	1	5	5	5	0	5	—	0
4	—	—	—	0	0	2	3	10	0	1	2	1	2	5	5	4	—	0
5	—	—	—	—	—	—	6	8	0	5	4	9	6	20	13	—	10	0
6	—	—	—	—	—	—	—	—	—	10	17	3	—	—	—	—	11	0
7	—	—	—	—	—	—	—	—	—	9	14	0	—	—	—	—	5	0
8	—	—	—	—	—	—	—	—	—	4	5	0	—	—	—	—	20	18
9	—	—	—	—	—	—	—	—	—	2	3	0	—	—	—	—	—	—

[a] See text and table B.4, appendix B, for explanation of rank classification.
[b] Sprinkler irrigation, no surface water.

Table B.3.—*Distribution of study sites within each rank by land use class, untilled (A_1), dryland farming (A_2), and private irrigation development (A_3) for six site characteristics (numbers within columns are the number of study sites)*

Rank[a]	Surface wetlands			Topography			No. of vegetation types			No. of fields			Adjoining sections with untilled land			Acres of untilled land		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
0	3	9	6	—	—	—	—	—	—	—	—	—	0	3	4	0	4	3
1	3	2	2	10	10	5	6	6	4	2	2	0	0	0	0	0	0	0
2	0	0	0	0	0	2	6	6	4	2	4	2	0	3	1	0	0	2
3	6	1	1	0	0	0	0	0	1	5	5	2	0	4	2	0	1	1
4	—	—	—	0	2	0	0	0	0	1	0	1	0	1	0	0	0	0
5	—	—	—	2	0	2	0	0	0	2	0	1	12	1	2	0	1	0
6	—	—	—	—	—	—	—	—	—	0	1	2	—	—	—	0	1	0
7	—	—	—	—	—	—	—	—	—	0	0	1	—	—	—	0	0	0
8	—	—	—	—	—	—	—	—	—	0	0	0	—	—	—	12	5	3
9	—	—	—	—	—	—	—	—	—	0	0	0	—	—	—	0	0	0

[a] See text and table B.4, appendix B, for explanation of rank classification.

Table B.4.—*Description of ranking system for six characteristics of study sites*

Water type

Rank

0 No surface water. May have sprinkler irrigation, but no collection of standing or flowing water.

1 Temporary surface water. Also includes canals, laterals, some drains.

2 Perennial drains.

3 Permanent surface water, excluding perennial drains.

Topography

Rank

0 Flat.

1 Gentle slopes, 5-30 degress, unidirectional aspect.

2 Gentle slopes, variable aspects.

3 Moderate slopes, variable aspects, contoured drainages.

4 Rough, broken, rock outcroppings, steep, and/or eroded drainages.

Vegetation types—on study section (includes crops)

Rank	Number of types
1	1–2
2	3–4
3	5–6
4	7–8
5	8–9

Fields—farmed fields or natural vegetation stands

Rank	Number of fields
1	1–2
2	3–4
3	5–7
4	8–10
5	11–14
6	15–20
7	21–25
8	26–30
9	>30

Adjoining lands—percent of eight adjoining sections having 15 or more acres of untilled land, exclusive of rights-of-way and water surfaces

Rank	Percent
0	0
1	13
2	25
3	38
4	50
5	⩾62

Table B.4.—*Description of ranking system for six characteristics of study sites*—Continued

Acres untilled—in study section

Rank	Acres
0	0– 1.0
1	1.1– 3.0
2	3.1– 6.0
3	6.1– 10.0
4	10.1– 15.0
5	15.1– 25.0
6	25.1– 50.0
7	50.1–100.0
8	> 100

APPENDIX C

DEFINITION OF FEATURES USED TO CLASSIFY WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

DEFINITION OF FEATURES USED TO CLASSIFY WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

WITHIN IRRIGATION PROJECTS – Includes waters within the boundary of an irrigation project (Kittitas, Yakima, and Columbia Basin).

I. Influenced by irrigation – There is some measurable effect upon the flow, lake level and/or quality of a water body resulting from irrigation operations.

A. Direct effect – Includes waters that are directly connected at some time to an irrigation system by means of surface flow (canal, drain, wasteway, or overflow due to high water).

1. Flowing waters – There are four types of flowing waters:

a. Streams – Waters following a natural course, the channel not being artifically constructed;

b. Canals – A primary project feature for delivery of water to various irrigation blocks;

(1) Structured – The channel is artificially constructed and usually a straight slot;

(a) Lined – The channel walls and bed are covered with concrete;

(b) Unlined – The channel walls are fashioned out of compacted earth or the natural substrate through which it passes;

(2) Unstructured – The channel follows a natural meandering course;

c. Drains – A secondary project feature designed to collect excess irrigation water;

(1) Structured (same as for canals)

(2) Unstructured (same as for canals)

2. Static waters – Includes all ponds, lakes, and reservoirs which are connected to an irrigation system by means of a canal, drain, or wasteway. They are stratified according to the following:

a. Age – The time in years since water first appeared. There are three age strata:

(1) One to ten years;

(2) Eleven to thirty years; and

(3) More than 30 years (includes all natural waters).

b. Size – Measured as the mean annual acreage or as reported by various sources. There are four size strata for each age stratum:

(1) Ten acres or less;

(2) Eleven to forty acres;

(3) Forty-one to one hundred acres; and

(4) More than 100 acres.

B. Indirect effect – Includes waters that are not connected directly to the system, but increase or decrease in level or flow as a result of irrigation operations. Lowering of the water table through ground-water pumping or raining the level through seepage from canals, drains, or wasteways are examples of indirect effects.

1. Flowing waters – There is only one type of water in this category:

a. Streams (same as I.A.1.a.).

(1) Surface flow – Water originates from drainage basin and tributaries.

(2) Seepage – Water originates from subsurface source (springs or wells).

2. Static waters – Includes all ponds and lakes not directly connected to an irrigation system. They are stratified as follows:

a. Age (same as I.A.2.a.).

b. Size (same as I.A.2.b.).

(1) Surface flow – Spring-fed surface flow or outlet from adjacent impoundment maintains level.

(2) Seepage – Impoundment level is maintained through subsurface flow

II. Not influenced by irrigation – There is no measurable effect of irrigation operations on flow or volume of the water body.

A. Flowing waters (same as I.B.1.).

B. Static waters (same as I.B.2.).

OUTSIDE IRRIGATION PROJECTS – Waters outside irrigation project boundaries and unaffected by irrigation.

I. Flowing waters (same as I.B.1.).

II. Static waters (same as I.B.2.).

APPENDIX D

LIST OF STATIC WATERS, INDEX NUMBER, TYPE OF FISH PRODUCTIVITY, AND IRRIGATION INFLUENCE

LIST OF STATIC WATERS, INDEX NUMBER, TYPE OF FISH PRODUCTIVITY, AND IRRIGATION INFLUENCE

Appendix D.—*List of static waters, index number, type of fish productivity, and irrigation influence*

ID No.	Type	Name	ID No.	Type	Name
1	SDP	Mesa	17	TIM	Hampton
2	SIP	White Bluffs	18	SDM	Long
3	TIG	Lenice	19	TIG	Harris
4	SDM	Red Rock	20	SDM	Keechelus
5	TIM	South Teal	21	SDP	East Ancient
6	TIP	Herman	22	SDP	Stan Coffin
7	TIG	Quail	23	SDM	Evergreen
8	TIM	Corral	24	TIG	Trinidad
9	SDG	Lower Goose	25	SDG	Crater
10	SDP	Soda	26	SDG	Crater Slough
11	NIZ	Migraine	27	TIM	Homestead
12	TIM	Poacher	28	NIZ	Black Rock
13	TIM	Marco Polo	29	TDP	Keechelus
14	NIZ	Beverly	30	SDM	Billy Clapp
15	TIP	Heart	31	SIG	Coffee Pot
16	TIG	East Sage	32	TIM	Jameson

S—Spiny-ray
T—Trout
N—No fish
D—Direct irrigation influence
I—Indirect irrigation influence
G—Good fish productivity
M—Medium fish productivity
P—Poor fish productivity
Z—No fish productivity

APPENDIX E

DEFINITIONS OF MORPHOMETRIC FEATURES MEASURED IN STATIC WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

DEFINITIONS OF MORPHOMETRIC FEATURES MEASURED IN FLOWING WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

Area (A) – The surface extent of a water body, in acres.

Volume (V) – The total volume of water in an impoundment. Volume was determined by calculating the volume of each stratum bounded by adjacent depth contours and then summing the volumes of all strata. Depth contours were measured from contour maps. Because slope of the lake bottom affects the horizontal plane area of each contour bounding a stratum, volumetric calculations of strata must take this into account. The volume of each stratum was calculated as follows:

$$v = 1/2\ (A_1 + A_2)\ d$$

Where A_1 is the area of the upper horizontal plane of a contour stratum, A_2 is the area of the lower contour of the same stratum, and d is the depth of the stratum.

Mean depth ($\bar{Z}$) – The ratio of volume to area.

Maximum depth (Z_m) – The deepest area of a lake as measured between the bottom and the surface of the lake.

Shoreline length (L) – The length of the shoreline.

Shoreline development (D_L) – This is a quantitative expression relating the length of the shoreline to the length of the circumference of a circle of the same area as the lake. It is calculated as follows:

$$D_L = L/2\ (\pi\ A)\ ^{1/2}$$

Where L is the length of shoreline, A is the impoundment area, and π is a constant value (3.1416). A perfectly round basin would have an index of 1.0.

Bottom slope (Z_r) – Slope characteristics and the amount of shoal or shallow water are important in calculating the zone of productivity (littoral area) in a lake. Gradual slopes or shoal areas are generally richer in biota than deep, steep-sided basins, owing to sunlight penetration and availability of substrate for attachment. The mean slope is expressed as a percentage ratio of the maximum depth to the mean lake diameter as follows:

$$Z_R = Z_m\ 50\ (\pi)\ ^{1/2}(A)^{-1/2}$$

Where Z_m is the maximum depth, and A is the area of impoundment.

Development of volume (D_v) – This is an expression of the shape of a lake basin and is represented as the ratio of the mean depth ($\bar{Z}$) to the maximum depth (Z_m). A low D_v ratio indicates conical-shaped basins whereas lakes with a high D_v ratio are steep-sided with flat bottoms. Further explanation of these variables are given in Reconnaissance Data on Lakes in Washington (Dion *et al.* 1976).*

* Dion, N. P., G. C. Bortleson, J. B. McConnel, and L. M. Nelson, "Reconnaissance Data on Lakes in Washington," Water-Supply Bulletin 32, State of Washington, 1976.

APPENDIX F

SCIENTIFIC AND COMMON NAMES AND IDENTIFICATION NUMBER OF FISH IN THE COLUMBIA BASIN, WASHINGTON

SCIENTIFIC AND COMMON NAMES AND IDENTIFICATION NUMBER OF FISH IN THE COLUMBIA BASIN, WASHINGTON

Appendix F.—*Scientific and common names and identification number of fish in the Columbia Basin, Washington*

Scientific name	Common name	Species ID No.
Order Salmoniformes		
Family Salmonidae		
Salmo gairdneri	Rainbow trout	1
Salmo trutta	Brown trout	2
Salmo clarkii	Cutthroat trout	3
Salvelinus fontinalis	Brook trout	4
Salvelinus malma	Dolly varden trout	5
Oncorhynchus tshawytscha	Chinook salmon	6
Oncorhynchus nerka	Sockeye salmon, kokanee	7
Coregonus clupeaformis	Lake whitefish	8
Prosopium williamsoni	Mountain whitefish	9
Order Perciformes		
Family Centrarchidae		
Micropterus dolomieui	Smallmouth bass	10
Micropterus salmoides	Largemouth bass	11
Lepomis macrochirus	Bluegill	12
Lepomis gibbosus	Pumpkinseed sunfish	13
Pomoxis nigromaculatus	Black crappie	14
Family Percidae		
Perca flavescens	Yellow perch	15
Stizostedion vitreum	Walleye	16
Order Cypriniformes		
Family Ictaluridae		
Ictalurus nebulosus	Brown bullhead	17
Ictalurus natalis	Yellow bullhead	18
Family Catostomidae		
Catostomus catostomus	Longnose sucker	19
Catostomus macrocheilus	Largescale sucker	20
Catostomus columbianus	Bridgelip sucker	21
Family Cyprinidae		
Cyprinus carpio	Carp	22
Mylochelius caurinus	Peamouth chub	23
Ptychocheilus oregonensis	Northern squawfish	24
Rhinichthys osculus	Speckled dace	25
Rhinichthys cataractae	Longnose dace	26
Richardsonius balteatus	Redside shiner	27
Gila bicolor	Roach, or Tui chub	28
Order Cottiformes		
Family Cottidae		
Cottus sp.	Sculpin	29
Order Gadiformes		
Family Gadidae		
Lota lota	Burbot	30

APPENDIX G

DEFINITIONS OF MORPHOMETRIC FEATURES MEASURED IN FLOWING WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

DEFINITIONS OF MORPHOMETRIC FEATURES MEASURED IN STATIC WATERS OF THE COLUMBIA BASIN IRRIGATION PROJECT, WASHINGTON

Width – The width of the water surface was measured to the nearest foot at each transect.

Depth – Stream depth to the nearest 0.1 foot was recorded at 2-foot intervals along station transects. Smaller streams were measured at 1-foot intervals.

Substrate – The substrate composition at each site was rated according to the following types:

1. Boulders – rocks over 12 inches in diameter;
2. Rubble – rocks 3 to 12 inches in diameter;
3. Gravel – rocks 0.01 to 3 inches in diameter;
4. Sand/silt – particles less than 0.01 inch in diameter;
5. Muck – soft clay or organic materials; and
6. Hardpan – hard clay materials.

The type of substrate material was determined by visual inspection.

Substrate color – A rating of one to three was given to substrate color as follows:

(1) light; (2) tan; or (3) dark.

Water type – Five water types were rated by the following definition:

1. Riffle – shallow area of stream where the water surface is broken into waves by substrate wholly or partly submerged. Riffles are usually less than 1 foot deep;
2. Glide – deep, moderate to fast-flowing water, with an essentially nonturbulent surface;
3. Flat – shallow area of calm water with little or no flow;
4. Pool – stream area that is deep and of low velocity relative to the main current; and
5. Plunge pool – the scoured area immediately below a waterfall.

Water color – A rating of one to three was given water color as follows:

(1) clear; (2) milky; or (3) muddy.

Bank stability – Stream bank stability was measured according to the length of eroding banks at each station and expressed as the percent of total length of both banks. Sluffing or sagging of stream bank materials was considered to be erosion.

Undercut banks – The length of each bank with undercuts greater than 0.5 foot was expressed as the percent of total length of both banks.

Discharge – Stream discharge was computed at each location and expressed as ft^3/s (cubic feet per second). A section of stream with uniform substrate, usually a glide, was used for the measurement. A Teledyne-Gurley direct-reading current meter measured water velocity in ft/s. Readings were taken at 0.2 and 0.8 of the water depth each 2 feet of stream width. From this, an average velocity was computed and multiplied by the area of each 2-foot section to obtain discharge. Total stream discharge equaled the sum of the discharge of each 2-foot section. The 0.6 method was used to measure discharge in streams less than 1 foot in depth. Cross-sectional measurements were reduced to 1-foot intervals for channels less than 10 feet in width.

APPENDIX H

DEFINITION OF TERMS USED IN ANALYSIS OF VARIANCE OF INDEPENDENT VARIABLE REGRESSED AGAINST STANDING CROP (g/acre-ft.) OF FISH IN FLOWING WATERS OF THE COLUMBIA BASIN, WASHINGTON

DEFINITION OF TERMS USED IN ANALYSIS OF VARIANCE OF INDEPENDENT VARIABLE REGRESSED AGAINST STANDING CROP (g/acre-ft.) OF FISH IN FLOWING WATERS OF THE COLUMBIA BASIN, WASHINGTON

Bankcvr – Type of bank cover: forest, brush, grass, exposed.

Cah – Calcium hardness.

Cl – Chloride ion.

Intercept – Point where regression line crosses y-axis.

Length – Of sample station (feet).

Colorbtm – Color of the bottom.

Mg – Magnesium ion.

Mndepth – Average depth (feet).

Mxdepth – Maximum depth (feet).

Na – Sodium ion.

Overveg – Overhanging vegetation; less than 3 inches, 3-12 inches, more than 12 inches.

Percenti – Percent cover by AQUEG1.

Ph2 – Hydrogen ion.

Ripvegi – Most abundant riparian vegetation: trees, shrubs, grass.

SiO2 – Silicone dioxide.

Stabilit – Percent of sampling station with eroded bank.

Substri – Type of most common substrate: boulder to organic debris.

Temperat – Water temperature.

Undercut – Percent of sampling station with banks undercut more than 6 inches.

Watertyp – Kind of water: riffle, glide, pool, plunge pool.

Width – Of sample station (feet).

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.